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SOME EFFECTS OF ALTERNATE ENERGY POLICIES ON CALIFORNIA ANNUAL CROP PRODUCTION

By
Richard M. Adams
Warren E. Johnston
and
Gordon A. King

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Some Effects of Alternative Energy Policies on California Annual Crop Production

by

Richard M. Adams, Warren E. Johnston and Gordon A. King*

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Some Effects of Alternative Energy Policies on California Annual Crop Production

INTRODUCTION

The level of production and the continuing growth of California's agriculture sector have been due to a number of favorable environmental and technological conditions. California's temperate Mediterranean-type climate, a well-developed system for tapping the normally ample water resource base, and relatively productive soils enable growers to harvest a diverse, high-yielding crop mix. Coupled with this benevolent natural resource base are high application levels of chemical fertilizers, pesticides, and mechanical energy.

During the period 1972-73, two major international "crises" arose which had a significant impact on agriculture--"food crisis" with increased demands for most field crops and the "energy crisis." Interfaced with both these developments were worldwide inflationary pressures observed during 1973 and 1974.

The rising element of uncertainty, in the form of future energy availability and prices during this period, caused concern over both the cropping mix and the general economic welfare of the on-farm agricultural sector. After two decades of energy abundance at stable or diminishing real prices, farmers were suddenly faced with curtailed supplies at rapidly rising prices (USDA, Statistical Reporting Service, 1975).

The Role of Energy in California Agriculture

Agriculture uses about five percent of all energy consumed in California, an equivalent of 39.4 million barrels of crude oil (all

forms of energy) in 1972 (Cervinka *et al.*, 1974). A summary of the total energy consumption, by energy type, is presented in Table 1. In terms of importance to agriculture, natural gas was the single largest component, representing 53 percent of the agricultural use of energy (in crude oil equivalent)--approximately 30 percent of the natural gas energy was used in the production of nitrogenous fertilizer. Approximately 400,000 tons of nitrogen-type fertilizer were applied by California farmers in 1972 (California Department of Food and Agriculture, 1973a). The availability of natural gas (the source of hydrogen in synthetic ammonia) for fertilizer manufacture is important to California agriculture.[1/] Should natural gas for manufacture of ammonia become limiting, the impact would be an increase in prices, for even if other forms of nitrogen could be expanded to take up the share of the market now controlled by ammonia fertilizer, these other forms are more costly, on a per-pound-of-nitrogen basis (USDA, Economic Research Service, 1972). About 87 percent of nitrogen in chemical fertilizers is from ammonia derived from the natural gas process (USDA, Economic Research Service, 1974).

Diesel fuel, the second most important energy source (nearly 18 percent), was used mainly for cultural, harvesting, and transportation operations. The percentage of total energy supplied by diesel fuel is increasing due to increases in the number of diesel-powered tractors; concurrently there is a relative decline in gasoline use (U.S. Bureau of the Census; 1964, 1969). While fertilizer prices have

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1/ During the energy shortfall of 1973, residential natural gas use was afforded top priority, while fertilizer production was relegated to a low priority class. Currently, however, fertilizer production enjoys a noninterruptible status.

TABLE 1

Energy Consumption, Statewide and Agricultural Uses, California, 1972

Energy source: (units)	Energy consumption			
	Statewide use	Agricultural use	Agricultural use in relation to total statewide use	Relative importance of energy source in agriculture
	(10^6 units)	(10^6 units)	(percent)	(percent)
Natural gas (therms)	23,588.5	1,214.2	5.1	53.1
Diesel fuel (gal.)	2,659.4	292.6	11.0	17.8
Gasoline (gal.)	10,037.9	195.2	1.9	10.5
LP gas (gal.)	458.9	52.6	11.5	2.1
Aviation gasoline (gal.)	42.7	9.0	21.0	.5
Electricity (kwh.)	135,241.7	10,575.3	7.4	16.0

Source: Cervinka, et al., 1974.

decreased somewhat from 1973-74 levels (as supplies increased), gasoline and diesel fuel continue to increase in price.

Increased prices or curtailed availabilities of energy-related inputs could affect the agricultural productivity of land and labor and the mix of field crops and vegetables, as well as levels of net incomes in agriculture. The 1972 estimated costs of fuel, pesticide and fertilizer energy inputs for field crops studied ranged from $11 to $55 per acre whereas costs for vegetables ranged from $43 to $256 per acre (see Table 2). On strictly qualitative grounds, it is difficult to argue the direction of change in production for field crops *vis-a-vis* vegetables should energy supplies be curtailed or become more costly in a relative sense. Although vegetables have higher costs of energy-related inputs, these costs expressed in relation to total variable costs show as much variation within vegetable crops as between vegetable and field crops (see last column of Table 2).

Possible Impacts of Rising Energy Prices or Curtailed Availabilities

Changes in California's cropping patterns could have pronounced effects on both state and national agricultural commodity markets, given the state's significant market share of many specialty crops. Additionally, the impacts of changing cropping patterns and revenues associated with changing levels of demand and energy input availability and price may affect the welfare of those associated with the agricultural sector including farmers, farm laborers, water agencies, land owners, processors, input suppliers, and consumers. For farmers, the result may be lower profits since the resulting crop mix will be less profitable (due to rising production costs) unless there are compensating changes in product price levels.

TABLE 2

Typical Energy Costs Per Acre in Relation to Total Variable Costs for Selected California Crops, 1972

Crop	Energy Costs				Total variable costs	Energy cost as a percentage of total variable costs
	Fuel[a]	Pesticides[b]	Fertilizer[b]	Total		
	dollars per acre					percent
Field crops:						
Barley	1.65	1.05	8.00	10.70	47.00	23
Beans	5.90	14.50	6.80	27.20	171.50	16
Cotton	5.24	38.00	12.00	55.25	251.90	22
Rice	3.77	14.94	14.00	32.70	150.00	21
Safflower	2.22	0.62	10.00	12.84	51.00	25
Sorghum	2.50	1.05	12.29	16.80	56.00	30
Sugarbeets	4.50	23.00	14.00	46.50	217.50	21
Vegetables:						
Broccoli	10.70	51.67	77.42	139.80	590.00	24
Cantaloupes	8.60	14.00	20.60	43.20	330.00	13
Cauliflower	10.30	73.90	117.00	201.20	939.00	21
Carrots	9.00	74.00	29.00	112.00	976.00	12
Celery	11.80	115.80	128.40	256.00	2,291.00	11
Lettuce	7.45	93.00	22.00	122.50	988.00	12
Onions	8.90	60.00	35.00	103.90	1,130.00	9
Potatoes	5.70	62.00	39.00	106.70	630.00	16
Tomatoes, proc.	7.35	55.49	20.00	82.85	540.00	15

Source: Costs are based on University of California Agricultural Extension Service cost studies averaged over major production areas within the state.

a/ Includes both diesel and gasoline fuel used directly in production of crops.

b/ Cost reflects prevailing market price (1972) for pesticides (petroleum based) and nitrogenous fertilizer (natural gas based) inputs. Thus, the per acre energy cost for each input represents total cost of material input, including the energy component (petroleum and natural gas), as well as nonenergy components.

For example, a reduction in California's vegetable production due to cropping mix changes could translate into higher prices at the farm and retail level. Should high labor-input crops be curtailed, total farm labor employment may decline, and traditional flows of work patterns through the state may be disrupted. If water demands fall as a result of changing crop patterns, there may be a need for water reallocation between producing regions, rather than continued pressure for new development, and the repayment capacity of existing irrigation districts and water agencies could be reduced. Changing demands for land could affect land values and rents. The suppliers of inputs to agriculture may experience changing profit levels, as a result of production shifts and changes. Others in the agricultural sector that utilize agricultural commodities as intermediate inputs, such as food processors and livestock production and processing firms, may also be affected.

The net effect of rising energy prices or curtailed availabilities is uncertain--the above paragraph merely illustrates possible ramifications that might be considered. We are not so ill-advised as to attempt an analysis which speaks to all of these concerns in our initial effort. Rather, we attempt here to examine some of the economic impacts of changing energy availabilities and prices, along with alternative levels of commodity demands, directly on California crop production and indirectly on primary producers and consumers, as groups.

The Study

As noted in the introductory comments, this study was formulated in 1974 shortly after emergence of the possible food and energy "crises."

It was developed in an attempt to analyze rather short-run questions about possible changes in levels of production and in product (commodity) mix for annual crop production on irrigated lands in California.[1/]

The specific objectives of this study are to evaluate the price, quantity, acreage, and "welfare" effects of changes in statewide and subregional energy restraints, in increased energy costs, and in product demand levels. These follow from the apparent inability to discern qualitatively the probable impacts of changing energy conditions on California agriculture.

This study employs a normative mathematical model of the California agricultural sector to analyze the specific objectives discussed above. The diversity of soil, climate, and irrigation water availability and cost, and their impact on yields and profitability, are reflected in definition of 14 homogeneous production regions throughout California. The price endogenous nature of the quadratic programming model, coupled with the inclusion of risk variables, provides the framework used to address the analysis of vegetable and field crop supply response. Regional seasonality in California's vegetable production is considered

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1/ Crops included within the study are major annual vegetable and field crops whose respective gross revenues exceeded $15 million per crop in 1972. Crops meeting this criterion include nine field crops--barley, beans, corn, cotton, grain sorghum, rice, safflower, sugar beets, and wheat--and 10 vegetable crops--broccoli, cantaloupes, carrots, cauliflower, celery, lettuce, onions, potatoes, tomatoes for fresh market, and tomatoes for processing. Total acreage of these crops in 1972 was 4,408,400 acres, or approximately 54 percent of total state crop acreage including both annual and perennial crops. In terms of importance with respect to annual crops, the 19 crops accounted for 88 percent of crop acreage and 89 percent of the gross value of the state's production. Perennial crops such as trees, vines and alfalfa hay are excluded from the study.

through the estimation of seasonal linear price-forecasting equations. These, along with price-forecasting equations for annual field crops, are integral components of the quadratic objective function of the mathematical model. This report first develops the analytical framework with reference to previous research, followed by sections describing demand relationships for vegetables and field crops, production coefficients, resource and institutional constraints, and crop response functions for alternative levels of fertilizer application. The results for a base period model (1969-1972) next examine the effect of explicitly including risk variability coefficients and the effect of statewide versus regional energy restraints. Results for the alternative models are compared to acreage and production levels actually observed during the historical 1969-1972 base period to check for reasonableness and comparability.

The study next uses a set of assumptions concerning the availability of energy-related inputs and their associated price structure, combined with assumptions concerning future levels of demand to examine alternative projection outcomes. The projection year, 1977, is selected as a near-term target for quantifying supply responses for several energy and demand alternatives. The energy alternatives include increased costs for nitrogen fertilizers and fuels (diesel and gasoline) and, in addition, the effects of 20 and 40 percent reductions in fertilizer and fuel. The final section of the study summarizes changes in consumers' and producers' surpluses for a set of energy availability and cost scenarios.

ANALYTICAL FRAMEWORK

Mathematical Model

The basic quadratic programming model is similar to that of Takayama and Judge (1964a) and discussed recently by Duloy and Norton (1975), but with some modifications to be discussed subsequently. Specifically, the objective function is of the form:

$$\text{Max } \Pi = q'(a + .5\,Dq) - c'\,q^* - c'Gq^*$$

where q is a vector of aggregate activity levels and q* is a vector of regional activity levels, both expressed in quantity units (e.g., 1,000 cwt. or 1,000 tons); a and D are elements of the linear demand structure of the form P = a + Dq where P is an n x 1 vector of prices, a is an n x 1 vector of constants and D is a negative diagonal matrix of price-quantity slope coefficients (implying zero cross-effects at the farm level); c is a vector of variable costs per unit of output for particular crops by region and soil type and G is a diagonal matrix of yield variability coefficients.[1/]

1/ See Carter and Dean (1960) for definition of variability coefficients. An alternative, and perhaps more realistic treatment of risk using yield variability coefficients would be to modify the last term, i.e., replace c'Gq with q'CGq, where C is a diagonal variable cost matrix of elements corresponding to the elements of the c vector. Thus, the risk marginal cost would rise with the square of quantity produced and hence the greater the production of a specific commodity, the greater the risk. Such a development would be consistent with conventional risk-diversification procedures. Note that this specification differs slightly from that presented recently by Hazell and Scandizzo (1974) and by Simmons and Pomerada (1975), where activity levels were expressed in hectares and then converted to quantity units consistent with the demand functions through inclusion of average yield matrices. This study's approach differs by casting activity levels directly in terms of demand units.

The objective function is bounded by a convex constraint set of the form $Aq \leq b$, where A is an M x N matrix of input-output technical coefficients, and b is an M x 1 vector of regional resource availability levels. The maximization of the objective function subject to the restraints is analogous to maximization of the sum of producers' and consumers' surplus under the competitive framework if we are dealing strictly with final products. We will return to this point in a later section, since we have included in our study some intermediate commodities such as feed grains.

On a methodological note, the A matrix consisted of 370 production coefficients and the demand matrix, D, included slope coefficients for nine field crops and for 28 seasonal vegetables. The solution procedure incorporates the slope coefficients and intercepts directly into the objective function rather than the segmented demand procedure suggested by Duloy and Norton.[1/]

Treatment of Risk

Incorporation of risk in quadratic models was discussed over 20 years ago by Freund (1956). Recently, Hazell and Scandizzo (1974)

1/ The quadratic programming problem was solved using a nonlinear programming algorithm developed at the University of California, Berkeley by Best (1973). This algorithm, identified as FCD (Feasible Conjugate Direction), when interfaced with the University of California, Berkeley ALPHAC simplex algorithm, provided a powerful mechanism for solving problems with nonlinear objective functions constrained by a system of linear equations. This software system was adapted and used on a CDC 7600 computer located at the Lawrence Radiation Laboratory, Berkeley facility. The integration of this system of software with the speed of the CDC 7600 provided an expeditious means for solving the numerous parameter alternatives to which the large study problem was addressed. Individual execute times for all model solutions was less than 42 seconds per run.

have renewed interest in the inclusion of risk in large programming models. Essentially, they add a risk aversion coefficient and a variance-covariance matrix of gross activity returns such that price and marginal returns are equated for each activity. Simmons and Pomerada's (1975) study of Mexican vegetable exports utilizes this procedure in testing alternative values of the risk aversion coefficient (from 0 to 1.5) to compare actual with model results. Lin, Dean, and Moore (1974) also have shown the validity of the risk-averse behavioral assumption for crops with large variation in income.

Risk is obviously an important variable in the analysis of agricultural supply response. Variations in a crop's income may be due to yield variability, price fluctuations, or both. Risk-averse farmers will be less inclined to produce extensive acreages of those crops with large variations in income (i.e., "high risk" crops). Thus, deterministic agricultural models, where all crops are treated as risk homogeneous (or risk free), are logically likely to overestimate production of "high risk" crops at the expense of "low risk" activities (Hazell and Scandizzo, 1974). Further, the conventional assumption of profit maximizing behavior by decision making units has been shown to be an inferior behavioral hypothesis for California farmers; for example, see Just (1974). Lin, Dean, and Moore (1974) found that inclusion of farmers' subjective attitude towards risk in the form of expected value (EV) frontiers provided more accurate estimates of actual supply response.

In this study, risk is confined to yields; input costs and price-forecasting equations are nonstochastic. The yield coefficient

of variation, estimated by the variate difference method (Carter and Dean, 1960) is used to modify regional variable cost per unit of output to give a risk cost for each crop. This differs from the approach used by Simmons and Pomerada (1975) which utilized a constant risk aversion coefficient across all crops. Lin, Dean, and Moore (1974) suggest that the use of yield variability coefficients derived from county data tends to underestimate the subjective risk associated with specific crops. However, yield variability coefficients are used in this study because of the absence of subjective risk data for crops by region. Thus, each crop's risk cost is the product of the specific regional variable cost element in the cost vector and the associated yield variability coefficient. As noted by Hazell and Scandizzo (1974), the risk term is essentially an additional marginal cost equal to the additional expected return for risk-averse farmers to compensate for risk in production. Further development of this model would be to consider more complex risk terms, including price or net income variability for individual crops and covariability among crops.

DEMAND RELATIONSHIPS

The purpose of this section is to present estimates of price-forecasting equations for the ten vegetable and nine field crops included in the analysis. Since seasonality of production is particularly important for vegetables, correct analysis of comparative advantage would appear to require estimation of seasonal demand functions. Many vegetables are produced in more than a single season. To reflect seasonal patterns of demand, 28 equations are derived for the ten vegetables. This provides a more realistic basis for appraisal of the comparative advantage of the 14 production regions throughout the state.

In the model, linear demand functions of the form "p = a + Dq" are specified at the farm level where p is an n x 1 vector of prices, a is an n x 1 vector of constants, D is a negative diagonal matrix of price-quantity slope coefficients, and q is an n x 1 vector of quantities. Note that a diagonal D matrix implies zero cross-effects for competing commodities at the farm level.

Major emphasis is placed on farm-level price-forecasting equations that attempt to capture the effect on California price of California production, production of other regions, and other variables. Thus, the general specification of the price-forecasting equation is of the following form:

$$Pc_i = f(Qc_i, Qo_i, S_i, Y)$$

where:

Pc_i = season average price received by farmers in California for commodity i,

Qc_i = seasonal production, California,

Qo_i = seasonal production, "other" U.S. production,

S_i = existing stocks, U.S.

Y = U.S. aggregate disposable personal income.

From an econometric viewpoint, it appears reasonable to treat the quantity produced as a predetermined variable. That is, for most vegetables, current year production is not affected by current values of the other variables in the same equation structure, particularly price. Quantity is then used as an independent variable in a least squares price-forecasting equation. This appears to be reasonable in the case of most vegetable commodities with the exception of processing tomatoes and perhaps market onions, where

institutional arrangements suggest interrelationships between current price and quantity. However, in the case of some field crops (notably, sugar beets, cotton, and rice) simultaneity is suspected. Estimates for those commodities where simultaneity was suspected are developed from estimates derived in more exhaustive demand studies of these crops (Blakley, 1962; King *et al.*, 1973; Bates and Schmitz, 1969; Houck, 1964).

This formulation was used for all seasonal demand relationships and crops with the exception of cotton, processing tomatoes, sugar beets, and safflower where market conditions were such that the model seemed inappropriate, and extraneous estimates were used. It should be noted that the econometric results for some of these demand estimates were disappointing with respect to "robustness," and some adjustments were made based on what are considered to be reasonable procedures, as discussed in footnotes to Tables 3 and 4 which follow.

Price-Forecasting Equations for Vegetables

In California, vegetables are harvested during 10 of the 12 marketing seasons reported by the USDA prior to 1973 (USDA, Statistical Reporting Service, 1972)[1/] as listed below for the vegetable crops included in this study.

1/ Since 1972, production is reported for four seasons only.

TABLE 3

Summary of Vegetable Price-Forecasting Equations[a/]

Vegetable	Adjusted intercept[b/]	Slope coefficient with respect to California production[c/]	Price flexibility with respect to California production, 1967-72
Broccoli			
Early spring	15.30	-1.520	-0.21
Fall	12.47	-3.280	-0.29
Cantaloupes			
Spring	9.54	-1.038	-0.19
Summer	8.23	-0.281	-0.36
Carrots			
Winter	9.19	-1.107	-0.41
Early summer	6.30	-0.901	-0.43
Late fall	6.00	-0.649	-0.11
Cauliflower			
Early spring	16.00	-5.670	-0.50
Fall	15.00	-4.030[d/]	[f/]
Celery			
Winter	10.06	-1.660	-0.81
Spring	9.59	-1.795	-0.69
Early summer	7.14	-1.099	-0.32
Late fall	7.08	-0.419	-0.63
Lettuce			
Winter	9.08	-0.314	-0.22
Early spring	12.23	-1.226	-0.33
Summer	7.09	-0.202	-0.10
Fall	10.31	-0.518	-0.41
Onions			
Late spring	5.36	-0.408[d/]	[f/]
Late summer	3.02	-0.072	-0.14
Potatoes			
Winter	4.53	-0.695	-0.65
Late spring	5.50	-0.148	-1.21
Early summer	5.38	-1.260	-1.22
Late summer	5.45	-1.227	-1.24
Fall	5.40	-0.442[d/]	[f/]
Tomatoes			
Processing	68.00	-2.480[e/]	-0.27
Tomatoes - fresh			
Early spring	15.88	-3.170	[f/]
Early summer	15.79	-0.575	-0.14
Early fall	16.63	-0.468	-0.18

a/ Additional information concerning estimated vegetable price-forecasting equations may be found in King, Adams, and Johnston (1978).

b/ Independent variables, other than "California production" were evaluated at mean levels and added to the intercept term, resulting in a general price-forecasting equation of the form: $Pc_i = a_i + d_i Qc_i$. Units of the intercept terms are in dollars per cwt for all vegetables, excluding processing tomatoes, which is in dollars per ton. The intercept was then "adjusted" to ensure consistency of 1972 prices and quantities; i.e., to ensure that 1972 quantity levels resulted in approximate 1972 prices when used in the price-forecasting equation framework.

c/ Units of the slope coefficients are million cwt for all vegetables, except processing tomatoes, which is expressed in million tons.

d/ Due to statistical insignificance of the estimated slope coefficient, the incorporated slope coefficient is derived from other season price-flexibilities for the same crop, at relevant price and quantity levels.

e/ Slope coefficient derived from King, et al. (1973).

f/ Price-flexibility not calculated due to use of other season slope coefficients.

TABLE 4

Summary of Field Crop Price-Forecasting Equations[a/]

Field crop	Adjusted intercept	Slope coefficient
Beans, Dry	18.85	-.001300
Cotton	40.20	-.0000296
Feed grains[b/]	1.86	-.0000023
Rice	7.38	-.000039
Safflower	135.00	-.005920
Sugarbeets	16.01	-.002655

a/ For those commodities estimated directly (beans, feed grains, and rice), the analyses are based on annual quantity and price data for the 1955-1972 crop years, with quantity expressed in 1000 cwt (beans and rice) or 1000 bu. (feed grains). Prices are in actual dollars per unit. Aggregate disposable personal income (in million dollars) is for the fiscal year. Basic data and sources are shown in Appendix tables of King, Adams, and Johnston (1978).

b/ The estimated feed grain intercept and slope coefficient are used interchangeably for barley, corn, grain sorghum and wheat within the base and projection models.

Season	Vegetable Crop
Winter	Carrots, Celery, Lettuce, Potatoes
Early Spring	Broccoli, Cauliflower, Lettuce, Tomatoes
Spring	Cantaloupes, Celery
Late Spring	Onions, Potatoes
Early Summer	Carrots, Celery, Potatoes, Tomatoes
Summer	Cantaloupes, Lettuce
Late Summer	Onions, Potatoes
Early Fall	Tomatoes
Fall	Broccoli, Lettuce, Potatoes
Late Fall	Carrots, Cauliflower, Celery

Price-forecasting equations reported in Table 3 are specified for each crop by season in which it is marketed (27 seasonal equations plus an annual estimate for processing tomatoes). Such complete specification is necessary, not only to account for variations in the price structure across seasons for a given commodity but also to more fully examine the comparative advantage of each of the 14 production regions within the model.

Price Forecasting Equations for Field Crops

Of the 19 crops included in the study, nine are field crops. Due to the presence of price supports and government and grower-processor mandated quota systems during the data period (1955-1972), the estimation of price-forecasting equations for the field crops sector (as reported in Table 4) was more unwieldy than for vegetables. The feed grains, because of California's position as a net importer, required recognition

of the feed-livestock balance. Cotton and rice prices were muted by government intervention, while sugar beet prices were affected by a combination of processor capacity scheduling and government quotas. Safflower production occurred under contractual arrangement, with prices set before production occurred.[1/]

A more complete discussion of the price-forecasting estimation procedure and results may be found in the report by King, Adams, and Johnston (1978). The supplemental report provides a discussion of the appropriateness of seasonal versus annual demand estimates in a price-endogenous model, as measured by ANOVA testing procedures. Basic data and sources for the estimates are also presented.

PRODUCTION COEFFICIENTS AND RESTRAINTS

The development of the data set for this analysis follows the procedure employed by Shumway *et al.*, (1970) in an earlier effort. More specifically, the data requirements for the model include the following: (1) specification of the production regions, and the associated cropping activities; (2) the regional constraints on land, water, energy, and processing capacities; (3) yields and costs for regional cropping activities; and (4) the input-output, or technical coefficients for each cropping activity.

1/ Just's (1974) analysis of supply response of California field crops includes a detailed discussion of the institutional relationships among field crops. Given recent developments (e.g., removal of government supply controls) some of those posited relationships may not be relevant for the 1977 projection models, particularly the role of price supports and acreage quotas on cotton, barley, wheat, rice, and sugar beets.

Regional definition is facilitated by classification of three key regional determinants--climates, soils, and water availability and costs. To achieve a sufficient level of homogeneity in these factors, 14 production regions were delineated, each with two irrigable soil types. The 14 production regions are identified on Figure 1. Most regions generally follow county lines. With respect to water costs, this is not unexpected, as institutional forces associated with California surface water development have tended to allocate water, and hence costs, along jurisdictional lines. There are, however, two areas (five regions--7 and 9; 12, 13 and 14) where climatological data warranted breaking regions across county lines. While complicating data compilation, such a delineation is necessary to insure a satisfactory level of homogeneity. In addition, two distinct soil types are specified within each of the 14 production regions. The two "soil subregions," each with differing levels of productivity, compete for the same regional nonland input base.

Resource and Institutional Constraints

Within any agricultural production region, there are possible constraints on the physical maximum production of a given crop or all crops in total. These constraints may be of a physical nature, e.g., resources such as land or water which are essentially fixed in quantity and immobile, or may be short run limits in the supply availability of essentially mobile inputs, such as fertilizer. Alternatively, the institutional constraints (such as fixed processing capacity, storage facilities and grower or government mandated quotas on maximum production) may in fact span several regions, limiting

FIGURE 1

California Production Areas and Regions

aggregate production from a number of regions. The production regions defined in this study are characterized by both types of constraints (i.e., limited supplies of mobile or immobile inputs and maximum production levels) on total regional production. Constraint levels for 1972 and projections to 1977 were required. In determining the physical inputs available for the production of the model crops, the requirements of the excluded crops must also be met. Appendix Table A.1 summarizes resource requirements for the excluded crops, on a regional basis.

Irrigable Soil

The State of California with a surface area of over 100 million acres is the third largest state in the United States. The regional acreages are also impressive, ranging from 1.3 million (Region 4) to over 31 million acres (Region 6). However, much of the land area within the state is not suited to irrigated agricultural purposes because of inherent soil limitations. In areas where soils are of arable quality, increased urbanization has resulted in loss of agricultural soils due to conversion into urban uses or to problems associated with proximity to urban areas. Hence, the total irrigable acreage for the 14 production regions is much less than the total state acreage. Table 5 summarizes total and irrigable acreages, by region. Irrigable acreages are listed by two classes or types; Type I soils are those with a Storie index greater than 60 and Type II soils have a Storie index of 60 or less, as presented in Appendix Table A.2. The resulting "available irrigable acreage" estimates are treated as the regional soil constraints for this study. Note that this inventory contains only soil of

TABLE 5

Total, Irrigable, and Available Irrigable[a/] Acreages, by Region and Soil Type, 1972

Production region	Total acreage		Irrigable acreage				Available irrigable acreage[a/]			
	Acreage	Regional as percentage of state total	Type I soil	Type II soil	Total	Regional as percentage of state total	Type I soil	Type II soil	Total	Regional as percentage of state total
	1000 Acres	Percent	1000 Acres			Percent	1000 Acres			Percent
Coastal										
1	2,928.6	2.9	84.1	120.0	204.1	1.0	83.6	108.0	191.6	1.2
2	4,873.9	4.9	186.0	623.9	809.9	4.0	88.5	596.2	684.7	4.3
4	1,301.3	1.3	160.8	83.4	244.2	1.2	124.9	80.8	205.7	1.3
7	3,758.3	3.8	269.6	303.2	572.8	2.8	202.4	286.1	488.5	3.1
9	3,697.3	3.7	176.9	520.8	697.8	3.4	135.9	517.1	653.0	4.1
12	6,387.3	6.4	456.7	413.4	870.2	4.3	324.3	410.1	734.4	4.6
Central Valley										
3	2,523.3	2.5	571.3	957.8	1,529.1	7.5	331.9	783.5	1,115.4	7.0
5	5,974.8	5.9	907.4	1,580.3	2,487.7	12.2	528.6	1,411.6	1,940.2	12.2
8	2,209.9	2.2	434.8	782.8	1,217.6	6.0	94.5	583.8	678.3	4.3
10	8,283.7	8.3	1,328.3	2,488.4	3,816.7	18.8	383.5	2,328.6	2,712.1	17.0
11	6,109.9	6.1	1,731.5	1,062.4	2,793.9	13.7	1,342.5	1,022.4	2,364.9	14.7
Mountain										
6	31,154.3	31.2	417.8	1,965.1	2,382.9	11.7	284.5	1,740.0	2,024.5	12.7
Desert										
13	17,137.9	17.1	144.0	677.7	821.7	4.0	-	632.5	632.5	4.0
14	3,706.1	3.7	496.8	1,421.9	1,918.8	9.4	288.4	1,233.8	1,522.2	9.5
STATE TOTAL	100,046.6	100.0	7,366.0	13,001.3	20,367.3	100.0	4,213.5	11,734.5	15,948.0	100.0

a/ Available irrigable acreage equals total irrigable acreage less that required for excluded crop production, as defined in Appendix Table A.1.

agricultural quality based on SCS soil classes I through IV (USDA, Soil Conservation Service, 1970).

Irrigation Water

Water use within California is approximately 37 million acre-feet per year (California Department of Water Resources, 1974a). Agriculture constitutes the largest component of consumptive water use, utilizing over 32 million acre-feet, or 85 percent of the total. The agricultural water total includes both surface and ground water. Statewide, the relative shares of surface and ground water are 60 percent and 40 percent, respectively, of total agricultural water. The importance of each type of irrigation water varies regionally. For example, the Central Coast Regions (7 and 9) use ground water exclusively, while at the other extreme the Southern Desert Region (14) relies on surface water for 97 percent of its needs.

Water availabilities by region are primarily based on the DWR information (California Department of Water Resources, 1974b) with adjustments required to obtain consistency with the model regions and reductions for excluded crop acreage water requirements. Estimates for 1977 reflected additional municipal and industrial (M&I) uses and assumed maximum sustainable ground water levels (California Department of Water Resources, 1974b) rather than the higher, overdraft affected estimates for 1972. Given the contractual nature of surface water supplies to agriculture, additional M&I requirements are taken primarily from ground water supplies. A summary of the 1972 water constraint estimates is provided in Table 6. Regional water costs, by specific irrigation district, are presented in Appendix Table A.3.

TABLE 6

State and Regional Total and Available[a/]
Irrigation Water and Costs
by Water Source, 1972

Production Region	Total irrigation water				Available irrigation water[a/]			
	Surface	Ground (excluding overdraft)	Total	Ground as percentage of regional total	Surface	Ground (excluding overdraft)	Total	"Blended" water costs[b/]
	1000 acre-feet			Percent	1000 acre-feet			$ per acre-foot
Coastal								
1	150.0	30.0	180.0	16.7	119.3	23.9	143.2	2.54
2	477.0	110.0	587.0	18.7	259.1	59.7	318.8	3.41
4	190.0	75.0	265.0	28.3	125.6	49.6	175.2	4.74
7	-	539.0	539.0	100	-	321.7	321.7	4.50
9	-	250.0	250.0	100	-	138.8	138.8	5.90
12	380.0	330.0	710.0	46.5	190.0	165.0	355.0	6.79
Central Valley								
3	1,507.0	775.0	2,282.0	34.0	680.8	350.1	1,030.9	5.35
5	4,230.0	1,230.0	5,460.0	22.5	2,786.2	810.2	3,596.4	2.01
8	3,098.0	500.0	3,598.0	13.9	1,241.6	200.4	1,442.0	2.79
10	3,497.0	1,420.0	4,917.0	28.9	763.3	269.3	1,032.6	7.01
11	2,800.0	670.0	3,470.0	19.3	1,351.1	323.3	1,674.4	11.29
Mountain								
6	1,121.0	146.0	1,267.0	11.5	185.3	24.1	209.4	5.71
Desert								
13	737.0	151.0	888.0	17.0	205.7	42.1	247.8	9.27
14	3,200.0	114.0	3,314.0	.3.4	699.4	57.0	756.4	3.19
STATE TOTAL	21,387.0	6,340.0	27,687.0	22.9	8,607.4	2,835.2	11,442.6	

a/ Available irrigation water equals total irrigation water less that needed for excluded crop production.

b/ Data relate to ground water pumping costs and surface water costs as shown in Appendix Table A-3.

Gasoline and Diesel

The aggregate on-farm consumption of gasoline and diesel fuel within California has been relatively static since 1955, with an increase in diesel fuel compensating for declining gasoline consumption (U.S. Bureau of the Census, 1954 to 1969). Of total energy consumption within agriculture (including processing and transportation), gasoline and diesel accounts for approximately 28.3 percent (Cervinka *et al.*, 1974).

The technique employed by Cervinka *et al.*, (1974) was used to determine levels of consumption for each production region. Total dollar expenditures on gasoline and diesel, by county, were derived based on the 1969 *Census of Agriculture, California, Part 48* (U.S. Bureau of the Census). Fuel quantities were derived from the expenditure information by using 1969 regional price estimates for both gasoline and diesel. The usage rate, by cropping activity, soil type and region, are provided in Appendix Table A.4. Given the rather constant level of total fuel consumption, it is assumed that 1972 levels closely resemble 1969 levels. The 1977 projected levels reflected a constant gallonage, but changing proportions of gasoline and diesel.[1/] As with other resources, the 1972 and 1977 estimates were adjusted for excluded crop uses. Table 7 contains a summary of 1972 and projected 1977 regional levels of gasoline and diesel fuels, in addition to input levels for nitrogen fertilizer and pesticide inputs, discussed in the following sections.

1/ Per acre technical coefficients for gasoline and diesel, by region, crop and soil type, are summarized in Appendix Table A-4.

TABLE 7

Available Energy-related Inputs (Fuel, Fertilizer, Pesticides),
1972 and 1977[a/]

Production Region	Fuel				Nitrogen Fertilizer		Pesticides
	1972		1977[a/]		1972 level	1977 level[a/]	1972 level
	Gasoline	Diesel	Gasoline	Diesel			
	Million gallons				Million pounds		Million pounds
Coastal							
1	1.323	0.423	1.254	0.453	0.273	0.287	0.038
2	5.120	0.353	4.855	0.378	3.680	3.864	1.710
4	4.272	1.626	4.051	1.742	14.169	14.169	0.674
7	6.794	4.586	6.442	4.913	29.719	31.205	10.153
9	5.844	4.741	5.541	5.080	26.631	27.963	2.323
12	10.152	2.016	9.626	2.160	29.916	31.412	15.757
Central Valley							
3	11.733	7.281	11.125	7.801	34.986	36.968	14.036
5	13.948	11.302	13.225	12.109	73.505	77.181	3.034
8	10.330	4.272	9.577	4.577	10.208	10.719	5.459
10	5.143	9.109	4.877	9.759	60.188	63.197	9.673
11	9.371	11.918	8.886	12.769	88.587	93.016	8.454
Mountain							
6	5.335	1.434	5.059	1.536	3.010	3.164	0.283
Desert							
13	6.312	0.610	5.985	.654	8.895	9.395	1.681
14	4.576	6.134	4.339	6.572	77.191	81.050	11.464
STATE TOTAL	100.255	65.803	95.060	70.503	460.956	483.608	84.539

a/ Estimated in 1974.

Nitrogen Fertilizer

Natural gas, as the basic raw material in the production of most forms of nitrogen fertilizers, affects the supply and cost relationships regarding production of such fertilizers, given the uncertainty concerning future natural gas supplies. Increasing residential and commercial demands, as well as deregulation of well head price, are all factors contributing to this uncertainty.

Prior to 1973, nitrogen fertilizers were readily available, at constant or decreasing real cost, in part due to over-expansion of the nitrogen fertilizer industry in the 1960's. In 1972, California farmers applied over 400 million tons of elemental nitrogen, an increase of 86 percent over 1960 (California Department of Food and Agriculture, 1973a). This overall increase translates into approximately a five percent annual growth in California fertilizer production.

To determine the regional levels of elemental nitrogen applications, data from the California Department of Food and Agriculture (1973a) series on fertilizing materials were used. The fourth quarter report of each calendar year contains a summary of total nitrogen fertilizers applied, as well as the N content, for each county. These values were adjusted to conform to the regional delineations and excluded crop demands. For 1977, a growth of five percent over 1972 levels is assumed in order to derive regional estimates which might be realistic in the absence of supply curtailment. The 1972 nitrogen levels, as well as projected 1977 levels, are given in Table 7.

Pesticides

Due to lack of response curves for pesticide application rates, attempts to quantify the relationship between pesticides (in the aggregate) and agricultural productivity involve very tenuous assumptions. In addition, there is a high degree of substitutability among a large number of insecticides. For example, the production of lettuce in California involves the application of over 190 separate pesticidal compounds (California Department of Food and Agriculture, 1973b). Further, there is increased interest in biological control.

The availability and price of crude petroleum are important to the production of pesticides because petroleum by-products constitute the active ingredient, or the base or carrier (or both), of most pesticidal compounds. Concern over future availability of ample petroleum supplies, and present price structure for crude petroleum are reasons listed by chemical industry spokesmen for elimination of some pesticides from existing product lines, for rationing of certain compounds to wholesalers, and for rapidly rising pesticide prices (personal communications).

The determination of the pesticide input vector is based on unpublished data from the California Department of Food and Agriculture's Agricultural Chemical Division. These data, which represent all pesticide applications involving restricted materials or applied by custom operators, are tabulated on a county basis for both total pounds applied and acres treated. Regional estimates were derived from the county data and adjusted to reflect the pesticide needs of excluded crops. The total poundages of pesticides for each region are presented in Table 7. There is no expected increase in pesticide

applications from 1972 levels, even in the absence of petroleum shortages. This conclusion is based on institutional forces governing production, marketing and application of pesticides (Howitt, 1975).

Institutional Constraints

Constraints on regional and aggregate production of specific crops are introduced due to presence of certain institutional arrangements. Institutional constraints are particularly significant in the production of cotton, sugar beets, rice, and safflower. During the base period of 1969-1972, government administered quotas on production of cotton, sugar beets, and rice were in effect. In addition, the processing of tomatoes, sugar beets, and oil seeds (cottonseed and safflower) were limited by existing processing capacity.

In the base period model, acreage constraints associated with the government quotas on cotton, rice, and sugar beets constitute upper limits on production of these commodities. In addition, the regional constraints on production are imposed to reflect the limited processing capacity within each region for those cases where transport of the crop into other production regions for processing was considered to be unprofitable. Also, oilseed production levels are constrained statewide by total processing capacity. Regional and statewide processing capacities for sugar beets were based on published data (Hills and Johnson, 1973) and on personal communication with Dr. F. Jack Hills, Agronomy Department, University of California, Davis. Maximum processing capacities for oilseeds were based on consultations with Dr. P. F. Knowles, Agronomy Department, University of California, Davis, and with industry spokesmen.

For the 1977 projection models, government quotas were not relevant, given the then current relaxation of such limitations, under the Food and Agricultural Act of 1973 which extended through the 1977 crop year. However, processing capacity placed constraints on the production of sugar beets, oilseeds, and processing tomatoes. Thus, these constraints were also included in the projection models.[1/]

Crop Yields and Cost Data

Most of the crops included in this analysis can be grown commercially in numerous regions. However, variations are frequently observed in yields over time between regions (for the same crop on the same soil) indicating an inherent regional production advantage with respect to specific crops. The impact of such yield variability is a regional production emphasis on those crops where a comparative advantage is held.

In addition to observed yield differences across regions, there exists yield variation associated with soil type. Soils of Type I are more productive than those of Type II, *ceteris paribus*. An assessment of such regional and soil yield variability is important for two reasons. First, given the nature of the technical coefficient matrix, yields serve to define the magnitude of per unit input demands (see discussion of models in Section II). Second, the variable costs of production (harvesting and related activities) tend to vary with yield; thus, yield variation must be accounted for in developing certain components of production costs.

1/ In both the base and projection models, aggregate production constraints were not significant, given that specific crop production did not reach these levels. However, some regional processing constraints did prove binding, as discussed subsequently.

Several sources of data were used to develop regional yield estimates. The basic sources are the county Agricultural Commissioner's Reports (annual publications), which exist for all counties with significant agricultural production. Secondary sources of information, such as University of California Agricultural Extension budgets, were used to cross-check the accuracy of the Agricultural Commissioners' estimates.

To reconcile differences in regional yields across sources, the higher yield was generally selected, based on the goal of approximating Type I soil yields under good management. Soil II yields were then derived from the Soil I yields by a downward scaling. The resultant crop yields, by region and soil type, are given in Appendix Table B.1, and projected yields for 1977 are based on Appendix Tables B.2 and B.3. Projected yields for 1977, based on secondary data (University of California Division of Agricultural Sciences, 1974) were then used as the base for crop yields with reduced levels of nitrogen fertilizer application.

Variations in yield by region and soil type affect costs of production. Cultural practices and input levels are often a function of the region and/or soil type, resulting in additional site-specific cost variation. Such regional and soil-based cost variation is needed to ensure adequate portrayal of comparative production advantages between regions and soils.

The production costs used in the model are based on University of California Agricultural Extension Service budgets (1974). These budgets cover a substantial proportion of crops grown within California and are often available for each geographical area in which the crop is grown. The budgets thus reflect regional dissimilarities in production costs.

CROP RESPONSE FUNCTIONS

Fertilizer response functions are required to assess the impacts of curtailed nitrogen availabilites (below projected 1977 levels) in several "shortfall" scenarios to be discussed. Response functions were developed from data provided by plant scientists within the University based on field trials conducted in various regions of the state. The resultant response functions allow the assessment of the impacts of reduced nitrogen supplies on crop yields and, hence, cropping activities and other measures of interest (levels of production, net revenues, and the use of complementary and substitute inputs).

Two shortfall scenarios are analyzed within the study model to portray uncertainty of future nitrogen supplies. A 20 percent and a 40 percent reduction in available elemental nitrogen was considered, based on suggestions from scientists of the Departments of Soils and Plant Nutrition, Agronomy, and Vegetable Crops, University of California, Davis. While there was divergence of opinion on the impact of such reductions on specific crops, the consensus was that reductions of this magnitude would result in perceptible yield reduction. Lesser reductions, of 10 percent, for example, were not thought to result in a significant impact on yields because it was felt that farmers generally used excess quantities during the base period.

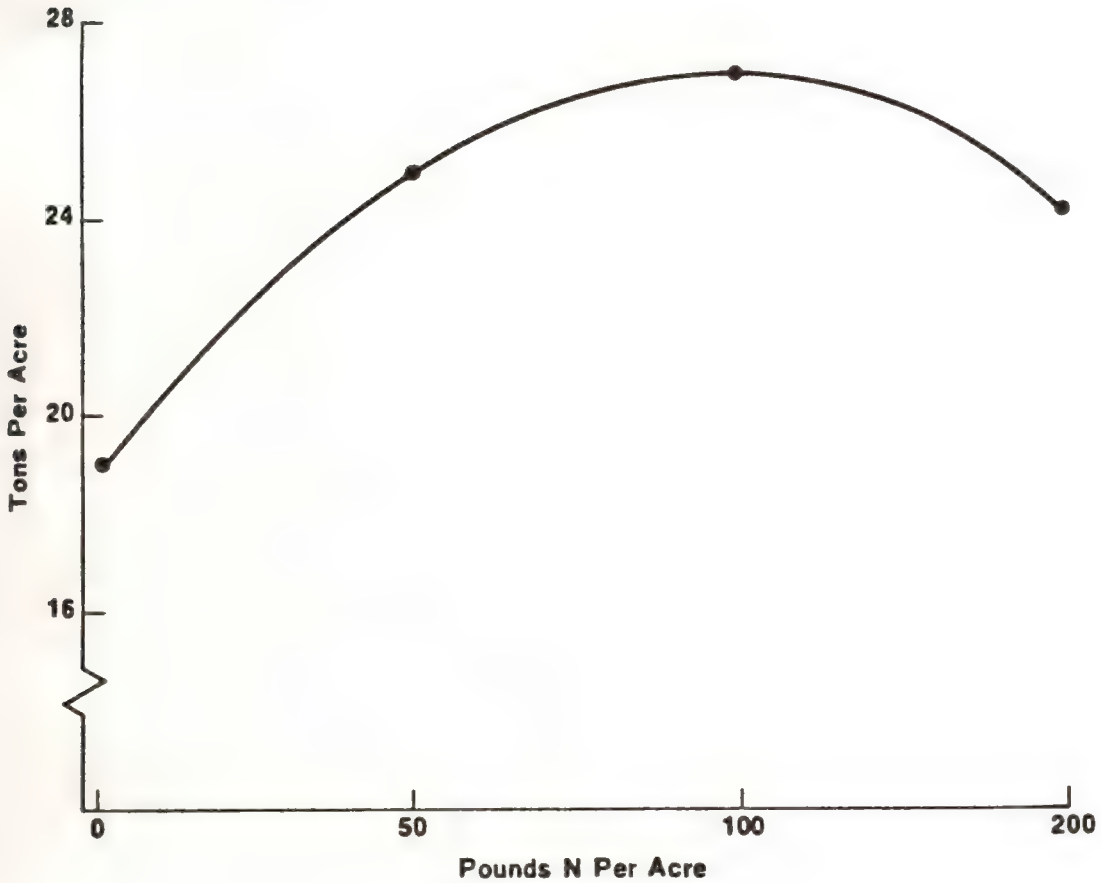
Four assumptions concerning crop production and cultural practices were made in using these response functions. First, it is assumed that there is no residual fertilizer left in the soil profile from previous applications; i.e., fertilizer applications are in equilibrium with crop use. Second, the response function for a given crop is homogeneous across all regions. Third, the response functions for a representative

crop (broccoli), may be used to depict the response of similar crops (cole crops). Fourth, it is assumed that the then current levels of application are not past the level of maximum physical product; i.e., they were not sufficient to depress yields or to cause physical injury to the crop. Such an assumption is needed to avoid increasing yields with decreased fertilizer application. The first assumption is not entirely correct in that it may take two years to leach residual nitrogen from the soil profile under a typical California irrigation regime (personal communication, Dr. R. Rauschkolb, Department of Soils and Plant Nutrition, University of California, Davis). Assumptions two and three are somewhat tenuous but lack of data for all crops and all regions precludes more exhaustive treatment. Assumption four is tenable in view of the generally high level of management displayed by California farmers.

Figure 2 indicates the general nature of a typical crop response function with yields measured on the ordinate and nutrient input levels measured on the abscissa. The impact of reduced levels of fertilizers on crop yields derived directly from the response function. In general, yields are reduced approximately 10 percent and 25 percent for the 20 percent and 40 percent nitrogen reductions, respectively, indicating the rather broad range of diminishing marginal product for fertilizer inputs. New sets of crop yield vectors were developed for both Type I and Type II soil in all regions. The resulting yield figures, by production region, are presented in Appendix Table B.3. For some crops such as cauliflower, the data to develop a response function were not available and response functions for crops deemed similar in physiological characteristics were used in determining yield reductions. Additionally, a general grain response function was used for all grains.

FIGURE 2

Typical Processing Tomato Response Function – Central Valley, 1968



Based on these yield estimates, the 1972 technical coefficient matrix (A matrix) was adjusted to reflect lower yields implying greater acreages are required to produce a given quantity (land and fertilizer are substitute inputs). Thus, a reduction in fertilizer supplied would be expected to result in crop production becoming more land extensive and increase the demand for the bundle of complementary production resources such as fuel, water, and pesticides. These resultant technical coefficient matrices are used in the 1977 analysis of the effect of reduced fertilizer supplies.

EMPIRICAL RESULTS

This section includes the following three general topics: (1) structure of California agriculture, 1969-1972, (2) empirical results for the base period model, and (3) 1977 projection model outcomes.

Structure of California Agriculture, 1969-1972

The period from 1969 through 1972 was one of relative stability for California agriculture, as shown in the descriptive statistics of Table 8. One possible reason for relative stability in acreages during this period (and for the entire 1960's) may have been the stability in federal prices and income policies that prevailed during that period. Government programs had a significant effect on supply response within the major production regions of California (Just, 1974). During all or part of the period 1969-1972, price supports were in effect on cotton, rice, barley, grain sorghum, and wheat. In addition, cotton and rice were subject to strict acreage allotments. Sugar beet

TABLE 8

Acreage and Production for Selected California Commodities; Mean and Range for 1969-1972 and Actual Values for 1973 and 1974 a/

Crop	Actual acreage levels				Actual production levels			
	1969-1972		1973	1974	1969-1972		1973	1974
	Mean	Range			Mean	Range		
	(1,000 Acres)				(1,000 Tons)			
Field crops								
Beans, dry	176.3	148.0- 214.0	161.0	227.0	135.3	107.0- 166.0	135.3	199.6
Cotton	766.5	662.0- 860.0	942.2	1,238.3	322.2	280.0- 773.0	420.0	612.0
Feed grains b/	1,269.8	1,077.7-1,372.5	1,160.2	1,140.4	2,052.0	1,635.7-2,511.9	2,208.8	2,174.8
Rice	369.2	331.0- 432.0	401.0	467.0	911.0	861.0-1,166.0	1,129.0	1,235.4
Safflower	200.7	145.0- 242.0	220.0	159.0	204.0	179.0- 237.0	123.0	155.0
Sugarbeets	302.9	254.0- 347.0	262.6	233.0	7,073.0	5,969.0-8,965.0	6,440.0	6,058.0
TOTAL FIELD CROPS	3,085.4	--	3,147.0	3,464.7	--	--	--	--
Fresh vegetables								
Broccoli	37.3	30.3- 48.0	49.0	44.7	137.0	99.7- 165.0	154.2	176.2
Cantaloupes	58.1	52.4- 68.0	53.2	36.2	433.0	363.3- 451.4	363.3	311.5
Carrots	26.9	23.4- 34.1	33.7	35.8	416.0	348.8- 493.0	491.5	598.8
Cauliflower	19.5	17.7- 23.3	24.6	28.0	97.0	87.3- 116.0	98.4	119.2
Celery	17.2	16.5- 19.0	18.6	18.3	484.0	459.2- 538.0	538.8	521.1
Lettuce	139.0	132.8- 141.6	143.4	149.2	1,648.7	1,442.6-1,735.5	1,746.7	1,752.2
Onions	24.9	22.3- 28.2	28.2	32.4	395.0	368.2- 437.5	377.7	542.7
Potatoes	81.9	67.2- 93.9	69.6	70.2	1,305.0	1,099.6-1,481.4	1,060.4	1,231.2
Tomatoes, Fresh	31.1	29.1- 34.7	31.5	31.5	327.0	290.2- 342.3	343.0	368.6
TOTAL FRESH VEGETABLES	436.0	--	451.8	446.3	--	--	--	--
Tomatoes, processing	181.8	141.0- 228.0	218.0	249.0	4,156.0	3,341.0-4,902.0	4,861.0	5,847.0
TOTAL, ALL CROPS	3,703.2	--	3,816.8	4,160.0	--	--	--	--

a/ California Crop and Livestock Reporting Service (1974a and 1974b).

b/ Estimated barley, corn, sorghum grain, and wheat grown on irrigated acreage.

growers received subsidies under the provisions of the Sugar Act. The impact of these policies was most pronounced in the major field crop areas--the Sacramento, San Joaquin, and Imperial valleys.

There were no serious disruptions in the physical resource and input structure during the period. Irrigation water supplies, both regionally and statewide, were adequate to meet annual demand (California Department of Water Resources, 1974b). Supplies of most inputs were readily available. The overall cost structure of prices paid by farmers remained relatively stable, with the prices paid by farmers increasing only eight percent between 1969 and 1972 (USDA, Statistical Reporting Service, 1975). Labor disruptions occurred during this period, but did not significantly affect vegetable production as they were directed primarily at grapes. Despite general concerns about the availability of agricultural workers particularly during peak harvest times, farm labor was in surplus supply during the base period (California Department of Human Resources Development, 1973). Weather conditions, particularly in the 1972 season, caused some production losses due to delayed plantings but none of the included commodities experienced major reduction in acreages.

The observed stability in total crop acreage and production also was evident in regional production; many commodities display high levels of regional concentration in part due to climatological determinants. For example, vegetable production is concentrated in the coastal and desert areas, grains and rice in the northern part of the Central Valley, and cotton in the southern Central Valley.

Base Period Model

There are three major purposes in the development of a base period model: to allow comparisons between base period model results and actual acreages, production and prices for the 1969-1972 period; to compare these same variables under alternative deterministic (or risk-neutral) and risk specifications; and to provide a basis permitting comparative evaluation of policy and other variable changes in the 1977 projection models.

The base period model is also used to analyze two important questions: What effect does the inclusion of a risk factor (yield variability) have on the resulting acreage, production, and prices, and on the resource use of model versus actual outcomes? and What are the effects of statewide versus regional energy restraints on these same variables?

Effect of Inclusion of Risk Factor

The results of this study provide additional evidence on the importance of specifying risk in normative programming models. Admittedly, the treatment of risk, measured by a yield variability coefficient, is but a first approximation to the more comprehensive analysis proposed by Hazell and Scandizzo (1974) and the sensitivity analysis done by Simmons and Pomerada (1975). However, as an empirical test, the model outcomes presented here may serve to expand interest in this important area.

The effect of introduction of the "risk" factor (as defined above) into the analysis was that acreage estimates for 13 of the 16 crops were closer to 1969-1972 actual acreages than base period deterministic model results. The difference between estimated and actual

levels of production was also reduced for 12 of the 16 crops. In the same context, estimated prices (for the weighted average of seasonal items) were closer to 1969-1972 prices for 11 of 16 crops. The results are as expected--vegetable acreage (higher yield variability) decreased in the aggregate while field crop acreage increased.

Review of possible limitations of this approach may lead to better modeling in the future. First, the amount of "improvement" was marginal for some crops. The acreage estimates for safflower, onions, and processing tomatoes were particularly high in relation to actual acreages. For the latter two crops, acreage is largely contracted by processors; thus the model does not reflect actual market conditions. For safflower, another contracted crop, the fault appears also to be partly related to the demand specification, since both price and quantity are above 1969-1972 levels. Note that for onions and tomatoes, higher production levels more correctly interact with the price-forecasting equation to give lower prices.

A second problem lies in the use of a single, uniform yield variability coefficient for the entire state. A more accurate specification would vary yield coefficients by region within the state. The third problem relates to the use of yield variability coefficients. As is evident from Table 9, coefficients of yield variability are less than those for gross income, suggesting that further research might use more complex risk terms. A comparison of yield and income variation coefficients in Table 9 would suggest that such a specification might lower vegetable production in relation to field crops.

TABLE 9

Effect of Introducing Risk Term in Objective Function on Acreage, Production and Prices, for Base Model[a/]

Crop	Variability coefficient associated with[b/]		Programming results					
			Acreage		Production		Prices	
	Yield	Gross income	No risk	Risk	No risk	Risk	No risk	risk
	(percent)		(percent of 1972 actual)					
Field crops								
Beans, dry	N.A.	N.A.	128	127	318	314	46	44
Cotton	7	20	126	129	139	142	152	155
Feed grains [c/]	6	5	59	63	68	69	114	113
Rice	6	18	46	47	53	54	126	125
Safflower	18	9	165	165	260	260	114	114
	6	11	60	67	64	72	108	107
TOTAL FIELD CROPS	--	--	85	88	--	--	--	--
Fresh vegetables								
Broccoli	11	9	157	132	167	140	98	103
Cantaloupes	10-16	15-16	112	100	122	113	71	73
Carrots	7-10	25-32	128	117	130	121	78	79
Cauliflower	7-11	21	88	76	106	92	110	118
Celery	5-16	19-50	127	117	130	120	82	87
Lettuce	6-12	19-33	130	113	126	116	94	101
Onions	6-13	16-39	235	225	297	285	55	58
Potatoes	5-18	26-40	107	94	90	80	102	110
Tomatoes, fresh	5-13	10-27	191	165	202	196	67	69
TOTAL FRESH VEGETABLES	--	--	133	118	--	--	--	--
Tomatoes, processing	5	11	177	172	313	280	65	67
TOTAL, ALL CROPS	--	--	95	96	--	--	--	--

a/ Statewide energy restraint model, excluding electricity.

b/ The ranges in yield and gross income for vegetables are for various seasons (Carter, et al., 1968).

c/ Estimated barley, corn, grain sorghum, and wheat grown on irrigated acreage.

Effect of Statewide Versus Regional Energy Restraints

In the general specification of the base period model, fossil fuel energy inputs are treated as perfectly mobile within and across production regions (there are only statewide constraints). This formulation is consistent with the energy supply situation of the late 1960's and early 1970's. However, as energy input supplies adjusted during the events of 1973-1974, several allocation programs were advanced, including a mandatory regional allocation policy. In turn, an implicit rationing scheme was imposed on agricultural users, based on past purchases from suppliers. While not totally fixing input supplies within a specific region, this scheme did reduce input mobility.

To examine the impacts of a rigid regional allocation policy, a second base model was evaluated for the period 1969 through 1972. Under this specification, each production region would receive levels of energy inputs comparable to average recorded usage during the period.

Table 10 provides results from these two base models along with averages for the period. In general, the results with respect to acreage levels and prices appear reasonable. Imposition of regional energy constraints generally reduced crop acreages, particularly in certain field crops, resulting in an attendant rise in commodity price levels--all but rice have acreage reductions and higher equilibrium prices. Vegetable acreages appear somewhat less sensitive to a regional allocation of fossil fuel energy inputs. The most striking exception is that for processing tomatoes, for which acreage declined rather sharply (approximately 40 percent)

TABLE 10

Effect of Introduction of Regional Versus Statewide Energy Restraints Within Base Models on Acreage, Production, and Prices, with Base Period Comparisons a/

Crop	Acreage			Production			Prices		
		Energy restraints			Energy restraints			Energy restraints	
	Actual 1969-1972	Statewide	Regional	Actual 1969-1972	Statewide	Regional	Actual 1969-1972	Statewide	Regional
	(1,000 Acres)			(1,000 Tons)			(Dollars per ton)		
Field Crops									
Beans, dry	176	224	157	135	426	307	285	135	197
Cotton	767	993	531	322	457	250	576	396	940
Feed grains b/	1,270	802	489	2,052	1,421	912	55	62	72
Rice	369	173	223	911	495	644	112	140	138
Safflower	201	332	145	204	531	232	113	130	132
Sugarbeets	302	199	192	7,073	5,100	5,054	16	17	17
TOTAL ACREAGE	3,085	2,723	1,737						
Vegetables									
Broccoli	37	49	36	137	192	142	210	215	232
Cantaloupe	58	58	56	433	489	435	141	124	128
Carrots	27	32	29	416	504	465	109	90	94
Cauliflower	20	15	13	97	88	66	198	223	246
Celery	17	20	19	484	583	538	107	95	99
Lettuce	139	158	141	1,649	1,918	1,763	101	102	108
Onions	25	56	34	395	1,130	734	77	39	46
Potatoes	82	77	68	1,305	1,035	864	59	63	70
Tomatoes, proc.	182	314	187	4,156	8,172	4,811	33	22	31
Tomatoes, fresh	31	51	48	327	917	846	294	205	210
TOTAL VEGETABLES	618	830	631						
TOTAL, ALL CROPS	3,708	3,553	2,368						

a/ Models include risk factor.

b/ Estimated barley, corn, sorghum grain, and wheat grown on irrigated acreage.

under the regional energy allocation model. Production and prices showed considerable variation in these models. The value of production of field crops in the statewide energy restraint model was 96 percent of actual and 99 percent of actual in the regional energy restraint model.[1/] For vegetables, comparable levels were 125 and 114 percent, respectively. Aggregating over all crops, the total value of production outcomes for a statewide allocation was 112 percent of the average 1969-1972 value and the regional restraint model was 107 percent of actual, a reduction of about five percent.

Thus, the implication of the regional allocation program is that a net cost would be incurred by agriculture due to a decline in the value of production. Accompanying this would be adjustments on the derived demand for inputs, particularly land. The imposition of regional allocation reduced total cropped acreage from 3.553 million (statewide model) to 2.368 million acres. A major reduction in land use would result in reduced returns to resource owners, unless offset by increased production levels of nonincluded crops (perennials and dryland).

Model vs. Actual Regional Cropping Patterns

The production patterns in model solutions reflect the comparative advantage of the 14 specific production regions included in the study. A comparison of model results (acreage), by production region, with actual

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1/ Calculated values, based on production and prices shown in Table 10, are as follows:

	Actual 1967-1972	Energy restraints statewide	Energy restraints regional
	million dollars		
Field crops	575.1	551.6	566.5
Vegetables	713.4	895.0	813.3
Total	1288.5	1446.6	1379.8

acreages, will serve to test the general reasonableness of the model parameters. This section examines the regional results for both the statewide and regional constraint base models.

To facilitate the presentation of regional acreages, the 14 production regions as previously identified in Figure 1 are aggregated into four major production areas identified as Coastal, Central Valley, Mountain, and Desert. The Coastal area contains regions 1, 2, 4, 7, 9 and 12; the Central Valley contains regions 3, 5, 8, 10, and 11; the Mountain area is represented by region 6; while regions 13 and 14 together constitute the Desert area. A comparison of each model and actual regional production is provided by Table 11. As is evident, both statewide and regional energy constraint models generally reflect cropping patterns for the major production regions. The Coastal area is dominated by vegetables; the Central Valley by grains, tomatoes, and cotton; the mountain area by onions, potatoes, and grains; and the desert area by vegetables and cotton. Such consistency between base model and actual crop distribution is encouraging, as it serves to enhance the credibility of any major cropping shifts suggested subsequently by projection model outcomes.

The regional distribution of crops under both allocation models are similar. The table shows that vegetable production is concentrated in Coastal and Desert areas, grains and rice in the Sacramento Valley region, and cotton and cantaloupes in the San Joaquin region of the Central Valley. The number of cropping activities which entered the model solutions (for both models) for major production regions, however, is typically less than the actual number of crops found within each region indicating the specialization of

TABLE 11

Comparison of Crop Acreage for Statewide and Regional Energy Constraint Base Model, with Actual, by Major Production Regions[a/]

Crop	Production region												Total		
	Coastal			Central Valley			Mountain			Desert					
	Statewide model	Regional model	Actual	Statewide model	Regional model	Actual	Statewide model	Regional model	Actual	Statewide model	Regional model	Actual	Statewide model	Regional model	Actual
	1000 Acres														
Field Crops															
Beans, Dry	0	0	44.1	224.0	156.6	130.5	0	0	0	0	0	1.8	224.0	156.6	176.3
Cotton	0	0	0	843.6	427.4	735.8	0	0	0	149.5	104.2	30.7	993.1	531.6	766.5
Feed grains [b/]	235.2	154.2	88.9	552.3	310.0	990.4	14.4	25.0	38.1	0	0	152.4	801.9	489.2	1269.8
Rice	0	0	0	173.5	222.8	369.2	0	0	0	0	0	0	173.5	222.8	369.2
Safflower	0	0	2.0	331.9	145.2	198.7	0	0	0	0	0	0	331.9	145.2	200.7
Sugarbeets	25.7	43.7	21.2	173.2	148.0	221.1	0	0	3.0	0	0	57.6	198.9	191.7	302.9
TOTAL FIELD CROPS	260.9	197.9	156.2	2298.5	1410.0	2645.7	14.4	25.0	41.1	149.5	104.2	242.5	2723.3	1737.1	3085.5
Vegetables															
Broccoli	49.3	36.5	36.6	0	0	0.8	0	0	0	0	0	0	49.3	36.5	37.3
Cantaloupes	0	0	0	51.7	50.0	46.5	0	0	0	6.6	5.9	11.6	58.3	55.9	58.1
Carrots	23.7	21.7	12.6	0	0	0.8	0	0	0	7.8	7.4	13.5	31.5	29.1	26.9
Cauliflower	14.7	13.2	19.5	0	0	0	0	0	0	0	0	0	14.7	13.2	19.5
Celery	20.2	18.6	17.2	0	0	0	0	0	0	0	0	0	20.2	18.6	17.2
Lettuce	97.7	70.2	76.5	0	11.2	13.9	0	0	0	60.9	59.6	48.6	158.0	141.0	139.0
Onions	0	21.0	3.7	12.9	12.6	11.0	43.6	0	1.5	0	0	8.7	56.5	33.6	24.9
Potatoes	18.5	15.0	12.3	52.6	47.9	48.3	5.9	5.5	15.6	0	0	5.7	77.0	68.4	81.9
Tomatoes, proc.	0	0	23.5	314.3	186.9	157.6	0	0	0	0	0	0	314.3	186.9	181.1
Tomatoes, fresh	36.7	35.0	10.0	8.7	8.7	18.3	0	0	0	5.7	4.3	2.8	51.1	48.0	31.1
TOTAL VEGETABLES	270.8	231.2	211.9	440.2	312.3	297.2	49.5	5.5	17.1	81.0	77.2	90.9	830.8	631.2	617.0

a/ Results are for risk models.

b/ Estimated barley, corn, sorghum grain, and wheat grown on irrigated acreage.

production often found in programming models. The Central Valley has the widest production diversity with 11 crops (of a possible 14) found in the statewide model solution and 12 crops in the regional solution.[1/]

The Demand for Land, Water, Fuel, Fertilizer, and Pesticide Energy Inputs

The physical and fossil fuel energy input demands are presented in Table 12. For comparative purposes, the quantities available of each resource are also given net of excluded and dryland crops. On a statewide basis, there are unused quantities of soil, water, and energy inputs associated with the model solutions. For specific inputs such as ground water, diesel fuel and pesticides, the excess or quantity not used is relatively small, indicating that acreage expansions could potentially be constrained at the 1972 levels of these inputs. However, there appears to be adequate quantities of land (of both soil types) and surface water to allow for future acreage adjustments. The rather large residual for gasoline is the result of exclusion of on-farm vehicles (pickups and automobiles) from the energy coefficients developed for each crop. Thus, if this substantial usage of approximately 61 million gallons (Cervinka *et al.*, 1974) is accounted for, the residual quantity (not used) is much lower (22 million gallons).

1/ An examination of regional vegetable production on a seasonal basis indicates that production in both models is compatible with actual seasonal production (see Adams, 1975, pp. 59, 141). The Imperial Valley section of the Desert area (region 14) dominates the production of winter vegetables, while the Central Coastal area (specifically regions 4, 7, and 9) is a major supplier of both early and late market vegetables.

TABLE 12

Land, Water, Fuel and Other Inputs: Comparison of Amounts Available and Amounts Used in Base Period Risk Model

Item	Units	Available	Quantity Used	Not used
Land and Water				
Soil type I	Million acres	4.20	1.52[a/]	2.28
Soil type II	Million acres	11.70	1.34[a/]	10.36
Ground water	Million acre-feet	2.79	2.57	0.22
Surface water	Million acre-feet	8.61	7.05	1.56
Fuel				
Gasoline	Million gallons	100.30	17.47	82.83
Diesel	Million gallons	65.80	65.30	0.50
Fertilizer and Pesticides				
Fertilizer	Million pounds	461.00	369.63	91.37
Pesticides	Million pounds	84.54	77.05	7.49

a/ The sum of Soil Type I and Soil Type II quantity used does not equal sum of the primal cropping activities due to the presence of double cropping activities in the optimal solution. The difference between the sum of quantity used and model cropped acreage equals acreage double cropped (290,000 acres for the risk model).

In the results discussed in this section, energy constraints have been assigned on a statewide basis. Given that energy supplies are not limiting in these outcomes, there are no imputed values for energy inputs derived from the dual solution. However, the fixed physical resources (land and water) are obviously of regional relevance. Regional imputed values for land and water are generated within the dual solution (see Table 13). The most constraining input is ground water, both in terms of regional frequency and imputed value. The high imputed values attached to ground water result from an assumption used in specifying input-output coefficients; namely, that ground and surface water coefficients are based on the percentage that each constitutes of regional water use. For example, if a region's total water use is comprised of surface and ground water in a 60-40 percent relationship, the applied water per crop acre reflects this ratio. However, rigid adherence to this ratio might not occur in actual practice. Rather, some surface water could be substituted for ground water, should the latter become exhausted, and vice versa. Hence, the extreme imputed values for ground water may be unrealistic.[1/] However, with respect to some regions with heavy, or total, dependence on ground water (regions 7, 9, and 11) the imputed values give some indication of water scarcity and the possible need for additional water developments to serve those regions.

1/ The fact that no region experiences total exhaustion of water (only one source of water is constraining) suggests the possible substitution across water types for any given region.

TABLE 13

Imputed Prices to Land and Water Inputs:
Base Period Risk Model

Area and subregion	Resource Input		
		Water	
	Soil I	Surface	Ground
	dollars per acre	dollars per acre foot	
Coastal			
1	-	-	$19.50
2	$5.9	-	-
4	-	$105.45	-
7	-	-	88.13
9	-	-	77.97
12	-	119.91	-
Central Valley			
3	60.20	-	84.81
5	9.75	21.76	-
8	-	-	463.93
10	-	-	261.77
11	-	-	222.71
Mountain			
6	-	-	557.66
Desert			
13	38.50	81.93	-
14	-	64.99	-

Regional institutional constraints were previously defined for sugar beets, oilseeds, and tomatoes. Specific regional crop production in both models was restricted as a result of these constraints. For example, sugar beet production in the Sacramento Valley portion of the Central Valley (region 5) is constrained by the slicing capacity of processors within that region. However, the state processing capacity for processed field crops and tomatoes is not met in the base model.

1977 Projection Model Outcomes

This portion of the analysis focuses on two major problems: What might be the effect on acreage and production under future alternative energy costs? and What might be the effects on acreage and production of further reductions in nitrogen fertilizer and fuel supplies? This evaluation is made by comparing projected 1977 outcomes under alternative energy scenarios with those from the base period risk model with regionally constrained energy levels.

Six projection models were used in evaluating effects of alternative fossil-fuel energy input costs. These incorporate three levels of commodity prices and two levels of input cost alternatives to approximate the range of possible outcomes. The actual 1973 price increases due to inflation and unstable domestic and export markets far exceeded that year's growth in population or real income, traditional factors associated with shifts in demand in *real* terms for farm products. By late 1974, farm level prices had softened somewhat but still remained at levels substantially above 1972 levels. The uncertainty of future prices is the reason that multiple sets of demand and cost projections were evaluated in the projection models.

Specifically, three sets of linear price-forecasting equations were included in the projection models to represent a low, medium, and high assumption concerning farm level price-quantity relationships. The intercept of each estimated 1972 price-forecasting equation is taken as the base, and is adjusted for the low and medium demand levels to reflect assumed commodity price increases of 25 percent and 50 percent over 1972 levels, respectively. The higher of actual commodity prices observed in 1973 and 1974 were used for the high price assumption (most commodities, particularly field crops and tomatoes, experienced price increases in excess of 50 percent in that period over 1972 levels). Such an adjustment in the intercept implies a parallel shift outward in the demand curves for the included commodities, i.e., no change in the slope coefficient.[1/]

Production costs for model activities are adjusted upward by 50 percent and 70 percent over 1972 levels. The 50 percent adjustment reflects an upward movement in costs equal to the actual and anticipated rate of increase for all nonenergy variable production costs. The higher adjustment rate of 70 percent represents a high energy cost scenario; 1972 costs are adjusted upward (and weighted) at rates which reflect a greater increase for energy inputs while maintaining the 50 percent increase for nonenergy variable production inputs.[2/]

1/ For these short-run projections, the major "shifter" is likely to be price-effects rather than relatively large population effects which which might have reduced the slope of demand curves for the projection year.

2/ Projected cost increases were derived from U.S. Statistical Reporting Service data (1975) on price movements with emphasis on nonenergy cost components. Regional variable costs of production, by soil type, for 1972 and 1977 (under both energy cost assumptions) are given in Appendix Tables B.4 and B.5, respectively.

The projection models feature additional modifications: namely, the yield vectors reflect expected increases in commodity yields over time, and input availabilities reflect anticipated changes in physical and energy related inputs for 1977 (see Table 7). Thus, each projection model as compared to the base models represents a set of four new parameter values--price intercepts, input costs, yields, and input availabilities.

Effect of Changes in Energy Costs and Demand Levels

Two alternative levels of product demands and two levels of energy costs are included in this analysis--see Adams (1975) for more general discussion. In terms of sensitivity analysis and reasonableness (with actual commodity prices observed in 1975-1976), the *moderate* and *high* demand projections appeared to be most valid. The two energy cost assumptions are referred to as medium cost (Mc) and high cost (Hc) models. This medium cost model (Mc) specifies increases for energy and nonenergy costs of 50 percent above the 1972 level. The high energy cost model (Hc) specifies energy costs 70 percent above 1972 while nonenergy cost increases are held at 50 percent. Thus, four projection models are assessed and are identified as Medium Demand-Medium Cost (MdMc), Medium Demand-High Cost (McHc), High Demand-Medium Cost (HdMc), and High Demand-High Cost (HdHc).

The effect of an increase in energy costs with a given level of product demand is to increase acreage and production of field crops and decrease acreage and production of vegetables (see Table

14).[1/] The overall acreage level increases by about one percent under the Medium Demand assumption. For the High Demand assumption, the overall increase in acreage is approximately five percent, again due to an increase in field crop acreage which more than offsets a decline in the acreage of vegetable crops.

The impact of an increase in commodity demand under a given cost level is to increase the absolute acreage of both commodity groups, as is evident from Table 14. However, the net effect of such a demand increase is to reduce the *relative* production of field crops *vis-a-vis* vegetables. Also, note that under the moderate cost assumption, an increase in demand level results in a slight decrease in overall production while the change in demand under high energy costs shows a slight increase in production as measured by the index numbers.

Effect of Reduced Energy Availabilities

This section emphasizes the impact of energy supply adjustments on the 1977 model outcomes discussed above.[2/] Two supply adjustments for fuel and fertilizer are examined: a 20 percent and a 40 percent reduction in available energy as compared with the 1977 projection model. Nitrogen supply reduction is first examined as such, and

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1/ It cannot be argued that this is an equilibrium solution unless the full consumer demand reactions are included. This is particularly difficult for crops that are intermediate products (feed grains) and vegetables that have multiple outlets.

2/ Under these energy alternatives, 1977 yields, as used in the 1977 projection models are adjusted downward to reflect lower energy input levels while variable costs are adjusted to reflect the lower rates of application for these inputs and thus lower harvesting costs, e.g., see Appendix Table B.3. With these exceptions, the energy reduction models are similar to the 1977 projection models.

TABLE 14

Effect of Changes in Energy Costs and Demand Levels on 1977 Model Acreage and Production

Demand assumption and crops	Acreage			Production		
	With energy cost:			With energy cost:		
	150% of 1972 (Mc)	170% of 1972 (Hc)	Change with higher energy costs	150% of 1972 (Mc)	170% of 1972 (Hc)	Change with higher energy costs
	1,000 Acres		Percent	Index number[a/]		Points
Medium demand (Md):						
Field crops	1,290.9	1,459.9	113	85	100	+15
Vegetables	942.4	794.0	84	119	100	-19
TOTAL	2,233.3	2,253.9	101	108	100	- 8
High demand (Hd):						
Field crops	1,595.0	1,831.5	115	82	91	+ 9
Vegetables	961.8	857.8	89	117	105	-12
TOTAL	2,556.8	2,689.3	105	106	101	- 5

a/ The price weights for index numbers are prices for the medium demand, high cost (MdHc) situation.

then as a combined reduction in nitrogen and fuel (gasoline and diesel). This results in four specific energy alternatives: a 20 percent and 40 percent reduction in nitrogen, and a 20 percent and 40 percent combined reduction of nitrogen and fuel. Using the Medium Demand-High Cost model, the results of the four alternative energy models are presented in Table 15.

The reduction in input levels would be expected to reduce production, but would this decrease be greater for vegetables or field crops? Results in Table 15 indicate that vegetable production would be maintained to a greater extent than field crops. Acreage of field crops shows a marked increase as a consequence of reduced fertilizer supplies. Given surplus irrigable land in most regions, the model solutions reflect the substitution of land for fertilizer.

Combined effects of nitrogen fertilizer and fuel reduction further reduce acreage levels from the nitrogen reduction models. Again, vegetable production remains viable, indicating that California would remain a significant supplier of vegetables even under rather adverse energy input conditions. Production of field crops tends to be reduced to a greater extent than that of vegetables under reduced energy availabilities.

The aggregation of vegetables and field crops into two groups masks some major acreage and production responses for particular crops. For example, Table 16 shows that under reduced fertilizer alternatives, cotton and rice acreage reductions are offset by large acreage increases in dry beans, safflower, and/or sugar beets within the field crop group depending on which model is considered. Vegetable crops, carrots and cauliflower show marked declines while some other vegetables remain constant or increase their respective acreages, for example, lettuce.

TABLE 15

Effect of Reduction in Nitrogen Fertilizer and Nitrogen Plus Fuel on 1977 Acreage and Production

Energy assumption and level of reduction	Acreage			Production[a/]		
	Field crops	Vegetables	Total	Field crops	Vegetables	Total
	(1,000 Acres)			(Index numbers)		
1977 base model (MdHc)	1,459.9	794.0	2,253.9	100	100	100
Reduced nitrogen (N)						
20%	2,062.1	806.2	2,868.3	90	98	96
40%	1,890.2	846.9	2,737.1	89	94	92
Reduced N and fuel						
20%	1,890.3	771.7	2,581.0	85	95	92
40%	1,612.9	677.3	2,290.2	64	80	76

a/ Laspeyres index using prices for 1969-1972.

TABLE 16

Effects of Reduction in Energy Quantities (Nitrogen and Nitrogen Plus Fuel) on Specific Crop Acreages and Production

	Acreage (MdHc)					Production (MdHc)				
	1977 Base model	Input reduction 20% Nitrogen	40% Nitrogen	20% N and fuel	40% N and fuel	1977 Base model	Input reduction 20% Nitrogen	40% Nitrogen	20% N and fuel	40% N and fuel
		(1,000 Acres)					(1,000 Tons)			
Field crops										
Beans, dry	232.4	256.5	287.2	289.3	247.5	451.9	435.9	392.5	416.6	282.0
Cotton	220.1	183.7	64.9	54.0	67.0	120.4	91.4	27.5	29.3	2.9
Feed grains[a/]	412.5	672.5	904.7	560.6	980.9	832.2	1,057.0	1,178.8	892.1	1,320.8
Rice	272.8	40.0	66.8	100.3	0.3	842.5	109.5	140.2	288.9	0.6
Safflower	184.3	811.9	177.3	645.0	37.9	274.2	834.8	166.8	688.2	28.4
Sugar beets	137.8	97.5	389.4	159.6	279.3	3,840.0	2,745.0	9,928.0	4,357.0	7,398.0
TOTAL FIELD CROPS	1,459.9	2,062.1	1,890.2	1,809.3	1,612.9	--	--	--	--	--
Vegetables										
Broccoli	32.1	38.1	50.2	22.2	13.7	126.9	142.9	175.7	82.3	48.0
Cantaloupes	59.6	64.5	63.0	64.8	62.2	487.5	477.3	483.1	475.2	477.8
Carrots	36.5	35.1	26.8	34.8	24.2	636.1	568.9	370.1	563.2	331.4
Cauliflower	7.6	7.4	0.3	5.1	.0	41.9	36.0	1.2	26.0	.0
Celery	21.7	21.3	24.0	21.3	22.1	630.8	601.7	649.0	601.5	595.0
Lettuce	188.7	175.0	222.0	180.4	205.9	2,292.9	2,348.5	2,900.9	2,345.3	2,698.4
Onions	42.1	37.3	44.6	36.6	38.4	953.4	798.0	893.9	781.7	768.1
Potatoes	87.3	83.9	84.9	77.3	52.8	1,117.8	1,036.5	988.4	968.0	627.7
Tomatoes, Proc.	250.6	269.5	277.8	256.3	207.7	7,325.0	7,408.0	6,680.0	7,031.0	4,916.0
Tomatoes, Fresh	67.8	74.0	53.3	73.3	50.3	1,184.3	1,153.6	920.1	1,148.4	868.7
TOTAL VEGETABLES	793.9	806.2	846.9	771.7	677.2	--	--	--	--	--

a/ Estimated barley, corn, sorghum grain, and wheat grown on irrigated acreage.

The effect of reduction of nitrogen and fuel at the 20 percent and 40 percent levels on individual crops can best be left to the interested reader. Comparison of results with 20 percent nitrogen reduction and 20 percent nitrogen and fuel reduction again shows less reduction in acreage and production of individual vegetable crops than field crops with the notable exception of sugar beets. Similar comparisons can be made with 40 percent reduction levels for nitrogen and for the combined nitrogen and fuel alternative.

WELFARE GAINS AND LOSSES

Theoretical Arguments

The maximand of the mathematical model used in this study is the sum of the areas under the crop demand curves (at farm level), less supply costs (including risk) associated with the optimal quantities of each crop activity. In a simple world of markets for *final products* without time, form and space dimension, it would be possible to discuss producer and consumer surpluses under the usual caveats associated with such concepts (Willig, 1976). Further, while an ordinal measure of consumer utility as derived from individual consumer's indifference maps may be theoretically correct and desirable, the estimation is infeasible. Hence, empirical research must rely on a measure of aggregate consumer utility which is computationally feasible, i.e., the area under a set of demand curves.[1/]

1/ Obviously, the measurement of change in consumer welfare associated with price adjustments must recognize related income effects. Willig (1976) treats the consumer good case and argues for the use of consumer's surplus as a tool in welfare economics. As he notes "I derive precise upper and lower bounds on the percentage errors of

(footnote continued on next page)

Market dimensions are ignored since prices are considered equal at all points in the state. An implicit assumption is that raw product prices are equal regardless of form (fresh or processed), except for specification of fresh and processed tomatoes as separate products. In this study, the treatment of consumer surplus considers both final products and intermediate products. The measure of consumer surplus measured at the farm level for a *final product* would equal that measured at the retail level if there were linear demand functions at both levels separated by a constant dollar marketing margin (R. A. King, 1975). That is, the two functions would be parallel and the point of intersection of relevant demand and supply curves for different market levels would occur at the same quantity level (raw product equivalent).

Discussion of consumers' surplus for *intermediate products* could cause a problem for a complete general equilibrium model, since consumers do not eat feed grains but rather meat and livestock products. Since livestock products are not included, the change in

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(footnote continued)

approximating the compensating and equivalent variations with consumer's surplus. These bounds can be explicitly calculated from observable demand data, and it is clear that in most applications the errors of approximation will be very small. *In fact, the error will often be overshadowed by the errors involved in estimating the demand curve.* The results in no way depend upon arguments about the constancy of the marginal utility of income" (emphasis added). One reviewer suggested we use the Willig approach which certainly would add elegance. We conclude that such refinement due to the admitted errors associated with the price forecasting equations might do more to mislead the reader than to adopt our approach admitting it is but a rough measure of welfare effects. Our approach then corresponds to that adopted by Dean and Collins (1967).

consumer surplus associated with some of the field crops is a proxy for the resultant change in consumer surplus in the final product market.[1/] Major emphasis in the analysis is given to *change* in consumer surplus from one situation to another rather than on the absolute magnitude of the values.

Producers' surplus in this model is generated by the difference in variable production costs between the marginal high cost area of production and the other lower cost producing areas. This sum is essentially a rent attributable to differential resource qualities in production regions given a set of demand levels for the various crops. Here again emphasis is placed on changes in producers' surplus which avoids the problem of inclusion or exclusion of certain fixed costs of management, etc.

The next step is to see how changes in energy costs and availability might affect the two aggregates of producers' and consumers' surplus.[2/]

1/ Schmalensee (1976), in a recent important development on consumers' surplus notes that "identical measures of the surplus change will be obtained in the affected input market and in the final product market even for substantial changes in input prices and costs."

2/ The aggregation of these two surpluses into a meaningful measure of social welfare involves complex criteria developed in the field of welfare economics. To make propositions concerning the change in aggregate surplus, welfare criteria must be applied to each situation. Depending on the criterion applied, the change in aggregate surplus may be described as a welfare gain or loss--and then, only if society is presumed neutral to the income redistribution involved. If income redistribution is presumed good or bad, indeterminate solutions can arise and the resolution requires the introduction of value judgments by policy makers.

Empirical Findings

There are four analyses discussed here: the effect of statewide versus regionally mandated energy allotments, the effect of increased energy costs, the effect of reduction in nitrogen supply, and the effect of reduction of nitrogen and fuel supplies.

Effect of Regional Energy Allotments

The impact of imposition of a *regional allotment* scheme for fossil fuel and nitrogen energy inputs is compared with the more flexible alternative in which inputs are mobile within the state (statewide allotment) by formulating the alternative schemes in the base period model. As shown in Table 17, Analysis 1, the regional restraint reduces the total value of the objective function by $264 million with roughly equal absolute decreases in consumers' (-$139.1 million) and producers' (-$124.5 million) surpluses. Consumers' surplus decreases due to the effects of higher consumer prices and lower levels of consumption, and producers' surplus is reduced due to distortions in production patterns because of resource immobilities.

Effect of Increased Energy Costs

An effect of *increased energy costs* is examined using the projection model with the regional energy restraints (Analysis 2) for the case which projects actual commodity prices at 50 percent over base period levels. Results given in Table 17 are reported in terms of 1972 dollars. The major impact of increased energy costs would be expected to result in increased production costs, with changes in producers' surplus related to changes in product mix, levels of

TABLE 17

Changes in Consumers' and Producers' Surplus Associated with Alternative Energy Assumptions, Expressed in Terms of 1972 Dollars[a/]

Analysis	Consumers' surplus	Producers' surplus	Total
	million 1972 dollars		
1. Effect of regional energy allotments[b/]			
Change associated with imposition of more stringent regional energy allotments as compared with statewide restraints.	-139.1	-124.5	-263.6
2. Effect of increased energy costs[c/]			
Change associated with high increase in energy costs (170 percent) as compared with moderate increase (150 percent).	-103.8	-129.3	-233.1
3. Effect of reduction in nitrogen supply[c/]			
Change associated with 20 percent reduction.	-11.1	-47.6	-58.7
Change associated with 40 percent reduction.	+13.6	-213.5	-199.9
4. Effect of reduction of nitrogen and fuel supplies[d/]			
Change associated with 20 percent reduction.	-25.6	-56.7	-82.3
Change associated with 40 percent reduction.	-67.2	-189.3	-256.5

a/ Analyses 2, 3 and 4 are expressed in 1972 dollars obtained by deflating values by the CPI.

b/ Based on results from base period risk model. See Adams (1974, p. 223) for further details.

c/ Based on results from 1977 risk model with medium demand increase and regional energy restraints.

d/ Based on results from 1977 risk model with medium demand increase, regional energy restraints, and high-cost increase.

production and commodity prices.[1/] The reduction in producer surplus exceeds that for consumer surplus in absolute dollar magnitudes ($129 vs. $104 million).

Effect of Reduction in Fertilizer Supply

The effect of absolute *reduction in fertilizer* supplies are given in Analysis 3 in Table 17. Producer surplus reductions of $48 million associated with a 20 percent reduction in fertilizer availability and $213 million for 40 percent are consistent with the optimal set of crop activities (see Table 16). The optimal *quantities* of each crop remain similar to the level of the base model but *acreages* increase to compensate for lower yields. Thus, producers' gross revenues do not change significantly while production costs rise roughly in proportion to the expanded acreage, resulting in lower net revenues. Since quantities produced are about the same under the alternative energy availabilities, consumer prices and hence magnitudes of consumer surplus remain relatively unchanged.[2/]

1/ Further research on the impact of increased energy costs on levels of consumer real income and allocation of expenditures on food and other commodities would provide a much more solid basis for exploring equilibrium conditions in these commodity markets. For some commodities, international trade is an added complication. The approach of this paper must be considered as a first approximation to a highly complex problem.

2/ The increase in consumers' surplus of $13.6 million (Table 17 analysis 3) associated with the 40 percent reduction in nitrogen supplies appears counterintuitive; however, inspection of Table 16 indicates increased production levels in certain crops (with associated lower prices) which contribute to this result.

Effect of Reduction in Nitrogen and Fuel Supplies

The impact of *reduced fuel supplies* tends to fall on consumers rather than producers. Compare results of Analysis 3 where nitrogen only is reduced with Analysis 4 where both nitrogen and fuel are reduced. For a 20 percent reduction, consumers' surplus changes from $-11.1 to $-25.6 million--a net reduction of $14.5 million. The reduction in consumers' surplus is much more severe for 40 percent reductions--$80.8 million. These results are due to a change in product mix where the comparative advantage of the *less* steeply sloped price-quantity commodities (field crops) is enhanced relative to vegetable crops (steeper sloped commodities). Therefore, the greater percentage reduction in vegetable commodities relative to field crops results in a more severe reduction in consumers' surplus vis-a-vis that of producers.

Viewed from a policy standpoint, information of the above type is useful for analyzing several issues pertaining to agriculture. For example, the cost of a policy aimed at reducing ground and surface water nitrate levels via a forced reduction in nitrogen would be borne mainly by producers under the model assumptions. Consumers' surplus increases by $13.6 million with a 40 percent reduction of nitrogen supply, whereas producers' surplus decreases by $213.5 million. Although the environment might be improved by a policy of nitrate reduction, the burden obviously falls on the producers under these assumptions.

An additional policy observation concerns the impact of combined energy reductions and high fuel costs. The relatively more severe impact on consumers associated with these adjustments implies that

subsidization of fuel use in California agriculture may actually be of greater benefit to consumers than to producers.[1/] A similar comparison with the effects of high and low energy costs on consumers indicates again that such transfer payments may result in a substantial benefit to consumers. The full welfare implications of such policy measures are complex and involve consideration of compensation principles of the Kaldor-Hicks variety.[2/]

CONCLUSIONS

Summary

This study has been an attempt to measure some general impacts on California agriculture of adjustments in energy costs and availability. Additionally, the study examines the feasibility of a particular methodological approach; namely, quadratic programming as applied to large, sectoral-level problems.

More specifically, the study has employed a comparative static quadratic programming model for a base period (1969-1972) and a projection year (1977) to provide quantitative estimates of possible price, quantity, and welfare effects that could be expected as a result of alternative energy input assumptions. The welfare effects of energy price and quantity parameter changes are evaluated by using the concepts of economic surplus.

1/ Such subsidization could be in the form of negative fuel taxes or full allocation of fuel demands, or both.

2/ For a brief discussion of alternative welfare criteria as applied to benefit-cost analysis see Merewitz and Sosnick (1971).

The base period model results suggest that the inclusion of regional energy restraints can affect cropping patterns. The results of a model incorporating such restraints, when compared with a statewide constraint specification base model, revealed the significant impact of such restraints. The most notable effect appears to be the sharp reduction in total cropped acreage for the state (1.1 million acres). This acreage curtailment occurred primarily at the expense of field crops, consistent with the traditionally lower per acre returns for this crop group. Aggregate vegetable crop acreage also declines; however, in addition, regional acreages were affected as the regional energy restraints were exhausted and the use of complementary inputs reduced.

It was observed that the inclusion of risk in the objective function, as suggested by Hazell and Scandizzo (1974), "improves" the normative model results in the sense that estimated quantities more nearly approximate actual quantities when compared with the model excluding the risk factor. Risk is included here simply by incorporating the yield variability factor associated with the individual crops; and, as might be expected, this variability is greater for vegetables than for field crops in general. It should be noted that the model is sensitive to cost and price-quantity slope and intercept values and that we do not argue for the predictive accuracy of a normative model. The results of this simplified risk model appear to be consistent with earlier research suggesting that California farmers are risk-averse in the relative planting of field crops *vis-a-vis* more yield-variable vegetable crops.

The empirical results for the projection models suggest that vegetable production in the aggregate will continue to be a viable cropping alternative for California farmers unless the overall level of commodity prices drops sharply. Within the vegetable group, some commodities, such as processing tomatoes and lettuce, show strong gains. Such a response suggests that this region's contribution to national commodity markets will remain significant. However, vegetable acreages are sensitive to high energy cost levels, as well as to availability levels. Measures of economic surplus indicate that adjustments may have differential impacts. Producers' surpluses in general are sensitive to energy availability levels, whereas consumers' surpluses are more affected by energy cost adjustments.

Critical Evaluation of the Methodology

This study has demonstrated that large quadratic programming problems can be solved efficiently. However, there are obvious limitations which must be recognized, including model specification, price-forecasting estimates, identification of production regions, underlying behavioral assumptions, and data aggregation. Such limitations are thus logical areas for further research.

The most apparent limitation is the partial equilibrium analysis in which the study model is cast. Only the California agricultural sector is handled explicitly within the study. All production adjustments in areas external to California are taken as given (held constant at 1972 levels). Hence, while the employed models display elements of general equilibrium analysis (through the use of price-forecasting equations), the study is, in a more universal sense essentially a partial equilibrium analysis. It is unlikely that production in other regions of

the U.S. will remain at 1972 levels while California producers alone are confronted with rising commodity prices, rising production costs, and input scarcity. The complexity of economic systems and the linkages between regional and national economies make any empirical analysis based on regional subsector analysis subject to qualification.

An outgrowth of the above general versus partial equilibrium issue is the static nature of the study. No cognitive or recursive process is recognized by which one year's (or time period's) parameter adjustments and outcomes interact with those for the subsequent year. Thus, any developments in the intervening four years (1973-1976) are ignored. As an example, during the 15 months of the study analysis, the "world" or environment surrounding California agricultural production has undergone substantial change. Further change is to be expected, and failure to account for the dynamic nature of economic issues may impart error to the projection outcomes. Again, however, true dynamic analysis of such a large complex problem area as the California agricultural sector exceeds current research capabilities.

The price-endogenous nature of the model places importance on the estimated price-forecasting equations. While the results for most crops appear acceptable, there are some inconsistencies in the estimated price-quantity relationships. Hence, some problems exist even though care was exercised in the development of the price-forecasting equations. Lack of alternative estimates makes the estimation process more tenuous, as there are few sources of comparisons. The model solutions also display a high level of sensitivity to small adjustments in the price intercepts. Given the importance of the price-forecasting equations in the quadratic formulation, the model results should be interpreted as conditional estimates.

Transportation and processing of agricultural commodities require more energy than actual production (Cervinka *et al.*, 1974). It is possible that from an overall energy-efficiency approach, the model cropping pattern may be quite different if transportation and processing were included. Finally, the projected 1977 parameters and the limited treatment of exports (in the price-forecasting equations) within the study may constitute limitations.

While recognizing these limitations, this study is a contribution to agricultural sector analysis, both with respect to refinement of an applied mathematical programming technique and data needed to facilitate its use. From a policy perspective, given the range of variables and parameters examined, the directional aspects of the models appear sufficiently well established to deal with broad policy questions of the type discussed within this study.

8/28/78 jma/gg

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APPENDIX A

SUPPORTING SOIL, WATER AND FUEL USAGE DATA

Table A.1

Regional and Aggregate Excluded Crop Input Demands, by Input, for 1972

Region	Total excluded Crop acreage	Irrigation Water Demands			Energy Inputs			
		Ground	Surface	Total	Nitrogen Fertilizer	Pesticide	Gasoline	Diesel
	(1000's)	(1000 acre feet)			(1000 pounds)		(1000 gallons)	
1	12.5	6.1	30.7	36.8	909.1	14.2	47.0	9.3
2	125.2	50.3	217.9	268.2	4,552.3	1,960.1	1,291.9	1,817.2
3	413.8	424.9	826.2	1,251.1	45,696.6	5,602.8	3,564.3	4,413.2
4	38.5	25.4	64.4	89.9	5,687.2	747.6	488.5	720.8
5	547.4	419.8	1,443.8	1,863.7	63,164.7	8,159.6	4,974.8	6,461.4
6	358.4	121.9	935.7	1,057.6	15,336.6	573.0	1,761.3	1,313.8
7	84.3	217.3	--	217.3	10,021.3	1,245.0	922.8	1,291.9
8	539.3	299.6	1,856.4	2,156.0	45,647.9	6,590.2	4,286.9	5,208.0
9	44.7	111.2	--	111.2	5,862.7	803.4	556.4	816.1
10	1,104.6	1,150.7	2,833.7	3,984.4	117,708.2	17,575.5	11,207.7	15,572.0
11	429.1	346.7	1,448.9	1,795.6	37,569.5	4,890.9	3,980.5	5,462.3
12	135.8	165.0	190.0	355.1	17,405.9	3,561.2	1,696.4	2,515.7
13	189.2	108.9	531.3	640.2	18,557.5	3,482.2	1,987.2	2,661.4
14	396.6	57.8	2,500.6	2,558.5	25,793.4	481.3	2,009.2	1,719.0
Total	4,419.4	3,505.6	12,879.6	16,385.2	419,923.8	55,687.0	38,775.0	49,982.1

Table A·2

Typical[a/] Storie Indices for Soil Series Contained in U.S.D.A.-S.C.S. Generalized County Soil Maps

Soil series	Storie index	Soil series	Storie index	Soil series	Storie index	Soil series	Storie index
Adelanto	62	Dagget	63	Landlow	50	Ramada	81
Ahwahnee	30	Delano	81	Laughlin	22	Ramona	77
Aiken	45	Delhi	42	Linne	46	Red Bluff	41
Aliso	36	Delpiedra	6	Los Banos	43	Redding	16
Altamont	36	Diablo	46	Los Gatos	32	Reiff	100
Alviso	19	Dinuba	58	Los Osos	50	Rincon	74
Arbuckle	69			Los Robles	95	Rocklin	48
Argonaut	53	Edison	38	Lost Hills	80	Rohnerville	55
Atascadero	52	Egbert	70	Loyalton	21	Rosamond	80
Atwater	68	El Peco	23			Rossi	26
Auberry	46	Eldei	80	Madera	57	Ryer	72
Auburn	33	Empire	81	Mayman	16		
Ayar	39	Exchequer	28	McCarth	0	Sacramento	47
		Exeter	61	Meloland	73	Salinas	90
Balcom	43			Merced	48	San Benito	53
Ballard	72	Foster	75	Metz	77	San Emigdio	70
Barey	41	Fresno	21	Millscholm	8	San Joaquin	27
Bayshore	86			Mocho	93	San Ysidro	45
Bishop	3	Garey	22	Mojave	60	Sehorn	40
Bottella	100	Gariota	48	Molinos	90	Sierra	50
Brentwood	81	Grangeville	90	Montpellier	40	Sites	58
		Greenfield	81	Mottsville	57	Sorrento	90
Cajon	56					Stockton	22
Calpine	69	Hanford	81	Nacimiento	34	Stutzville	72
Calvista	34	Henneke	18	Naylor	34	Sycamore	56
Campbell	65	Hesperia	92	Newville	34		
Capay	56	Hilgate	72			Tangir	24
Carrizo	54	Hilmar	47	Oakdale	60	Tehacapi	55
Castro	32	Holland	90	Oakley	45	Tehama	76
Chino	60	Holtville	54	Oceano	48	Temple	77
Chula	81	Honcut	90	Orestimba	28	Thermal	80
Cibo	18	Hverohuero	50			Tierra	30
Cibola	30			Pachappa	86	Traver	29
Clear Lake	47	Imperial	54	Pacheco	60	Trigo	27
Climara	38			Panhill	95	Tujunga	62
Coachella	43	Josephine		Panoche	80	Tulare	15
Cohasset	58	(2-30% slopes)	43	Pasquetti	57	Tyndall	77
Colma	45	Josephine		Pentz	15		
Columbia	85	(2-30% slopes, eroded)	36	Perkins	60	Valdez	81
				Pescadero	16	Venice	70
Cometa	44	Josephine		Peters	38	Vino	100
Conejo	77	(30-50% slopes)	20	Pinto	40	Visalia	86
Corning	23			Pits	5	Vista	36
Corralitos	77	Keeters	32	Pleasanton	85		
Cortina	47	Kettleman	32	Pond	14	Waukena	34
Cotati	70	Kimball	45	Porterville	45	Whitney	48
Coursegold	10	Kneeland	25	Positas	22	Willits	68
Cropley	60					Willows	26
Cuyama	24					Yokohol	30
						Yolo	90
						Zamora	90

a/ For some soil series, divergencies exist in the assigned Storie Indices found within the county soil surveys used as sources. Where such divergencies occurred, the Storie Index assigned to the more prevalent (in total acreage) soil series (or phase) was generally selected.

Source: Based on examination of Storie Indices as presented in available detailed County Soil Surveys.

Table A 3

Regional Ground, Surface and "Blended" Water Costs, by County and District[a/]

Region	County	Ground water		Surface water			Regional "blended" water cost
		Pumping cost	Percentage of total water	District	Deliveries	Water cost	
		$ per acre-foot	percent	item	1000 acre-feet	$ per acre-foot	$ per acre-foot
1	Del Norte	2.58	16	N.A	N.A	N.A	2.54
	Humboldt	2.50	16	N.A	N.A	N.A	
2	Lake	2.50	21	N.A	N.A	N.A	3.41
	Marin	3.09	32	N.A	N.A	N.A	
	Mendocino	2.40	16	Potter Valley	10.2	5.75	
	Napa	2.85	32	N.A	N.A	N.A	
	Sonoma	3.01	32	N.A	N.A	N.A	
3	Contra Costa	4.29	32	East Contra Costa	360.8	9.30*	5.35
				Byron-Bethang	258.6	7.87*	
	Sacramento	4.84	35	N.A	N.A	N.A	
	San Joaquin	5.74	35	Banta-Carbona	50.4	5.66*	
				South San Joaquin	258.0	3.01	
				Westside	42.2	6.55	
				Woodbridge	N.A	N.A	
	Solano	3.28	32	Solano	118.9	8.45	
4	Alameda	4.32	32	N.A	N.A	N.A	4.74
	Santa Clara	5.14	32	N.A	N.A	N.A	
5	Butte	3.11	21	Richvalle	113.9	1.87	2.01
	Colusa	4.23	21	Maxwell	68.8	3.44*	
	Glenn	3.03	21	Glenn-Colusa	718.1	1.53*	
				Provident	89.9	1.59*	
				Princeton-Codura-Glenn	N.A	N.A	
	Sutter	2.75	21	N.A	N.A	N.A	
	Tehama	4.38	21	Deer Creek	8.7	0.94*	
				El Camino	15.1	5.52*	
				Thomas Creek	5.1	2.84*	
	Yolo	3.72	21	N.A	N.A	N.A	
	Yuba	2.60	21	Brown's Valley	20.1	8.52*	
				Cordua	50.0	0.51*	
6	Calaveras	7.68	21	N.A	N.A	N.A	5.71
	El Dorado	N.A	N.A	El Dorado	14.2	42.16[b/]	
	Modoc	2.90	21	Hot Springs Valley	13.2	0.48	
				South Fork	20.6	0.34	
	Nevada	N.A	21	Nevada	69.1	14.65*	
	Shasta	3.57	21	Anderson-Cottonwood	149.8	1.24	
	Siskiyou	2.59	16	Butte Valley	14.1	2.37*	
				Scott Valley	15.0	0.94	
				Tule Lake	117.6	3.98	
7	Monterey	4.84	90	N.A	N.A	N.A	4.50
	San Mateo	2.78	32	N.A	N.A	N.A	
	San Luis Obispo	5.01	90	N.A	N.A	N.A	
	Santa Barbara	6.18	90	N.A	N.A	N.A	
	Santa Cruz	3.69	90	N.A	N.A	N.A	
8	Merced	4.23	17	Central California	543.8	2.62	2.79
				El Nido	5.5	9.74*	
				Grasslands	47.8	3.26*	
				Merced	446.4	3.81	
				Panoche	97.8	8.43*	
	Stanislaus	4.79	17	Modesto	231.6	0.40	
				Mustang	11.6	5.54*	
				Oakdale	212.4	2.61*	
				Sunflower	10.3	6.65*	
				Turlock	459.7	1.11	

(Table continued on next page.)

(Continued)

Region	County	Ground water: Pumping cost	Ground water: Percentage of total water	Surface water: District	Surface water: Deliveries	Surface water: Water cost	Regional "blended" water cost
		$ per acre-foot	percent	item	1000 acre-feet	$ per acre-foot	$ per acre-foot
9	Monterey	4.84	90	N.A	N.A	N.A	5.90
	San Benito	7.55	90	N.A	N.A	N.A	
	San Luis Obispo	5.01	90	N.A	N.A	N.A	
	Santa Barbara	6.18	90	N.A	N.A	N.A	
10	Fresno	4.46	17	Consolidated	86.7	6.17	7.01
				Fresno	276.5	5.60	
				James	67.2	6.36	
				Laquna	44.7	3.26*	
				Tranquility	33.1	7.08*	
				Westlands	824.2	9.06	
	Madera	5.87	17	Chowchilla	236.0	2.63*	
				Madera	96.7	11.95	
	Tulare	7.34	38	Alta	127.8	3.52*	
				Ivanhoe	11.6	14.39*	
				Lindmore	41.7	9.81*	
				Lindsay-Strathmore	25.8	17.66*	
				Lower Tule River	100.5	6.90	
				Stone Corral	8.4	16.20*	
				Teapot Dome	4.6	22.71*	
				Terra Bella		26.70*	
				Tulare	100.3	5.88	
11	Kern	11.90	38	Arvin-Edison	187.0	10.78	11.29
				Delano-Earlimart	120.7	6.65	
				Dudley Ridge	42.4	11.30	
				Kern County Water Agency	382.9	18.79	
				Shafter-Wasco	55.1	8.01*	
	Kings	5.57	38	Corcoran	72.5	4.68*	
				Empire-West	6.8	9.33*	
				Hacienda	5.9	5.80	
				Lakeside	N.A	N.A	
				Stratford	9.5	6.89*	
				Tulare Lake Basin	252.4	9.08	
12	Los Angeles	8.38	36	N.A	N.A	N.A	6.79
	Orange	10.10	36	N.A	N.A	N.A	
	San Diego	3.48	36	Vista	8.0	103.00 b/ *	
	Ventura	3.72	36	N.A	N.A	N.A	
13	Los Angeles	8.38	36	N.A	N.A	N.A	9.27
	Riverside	9.79	5	Palo Verde	435.1	3.46	
	San Bernardino	9.64	90				
14	Imperial	10.68	5	Imperial	2,380.8	2.83	3.19
	Riverside	9.79	5	Coachella Valley	N.A	N.A	

* Costs based on 1967 data.

a/ Water costs, unless otherwise noted, are based on 1972 data and are for agricultural uses.

b/ Includes residential sales as well as agricultural.

Sources: Ground water: 1) California Department of Water Resources [1972].
2) Pacific Gas and Electric Company Agricultural Power Schedules.
3) U.C. Agricultural Extension [1971].

Surface water: 1) California Districts Security Commission, San Francisco [1974].
2) Bank of America [1964].

Table A.4

Cropping Activity Fuel Usage (Diesel and Gasoline)
by Region and Soil Type, 1972

Region	Cropping activity	Type I soil		Type II soil	
		Total diesel	Total gasoline	Total diesel	Total gasoline
		gallons per acre			
1	Beans	16.75	3.76	16.13	4.33
	Potatoes	24.14	4.83	23.53	4.60
	Tomatoes, F	25.05	5.40	24.92	5.35
2	Barley	5.82	1.18	5.69	1.10
	Corn	9.56	2.67	9.40	2.58
	Wheat	5.83	1.18	5.70	1.11
3	Barley	6.70	1.66	6.44	1.52
	Beans	23.50	6.27	22.27	5.81
	Carrots	33.35	10.88	32.66	10.71
	Corn	10.96	3.41	10.57	3.20
	Gr. sorghum	9.03	3.31	8.75	3.19
	Lettuce	24.39	11.05	23.86	10.45
	Onions	32.94	11.06	32.70	10.95
	Potatoes	24.79	5.07	24.14	4.83
	Rice	20.81	0.84	19.09	0.75
	Safflower	9.56	1.95	9.56	1.94
	Sugar beets	19.17	4.11	17.85	4.11
	Tomatoes, F	29.16	6.98	28.61	6.77
	Tomatoes, P	30.20	7.37	29.55	7.12
	Wheat	7.47	2.09	7.21	1.95
4	Barley	6.19	1.38	5.69	1.10
	Broccoli	37.05	13.70	36.76	13.28
	Cauliflower	33.50	15.07	33.13	14.53
	Celery	36.18	15.52	35.42	14.41
	Lettuce	24.54	11.21	24.00	10.61
	Onions	33.14	11.15	32.88	11.03
	Safflower	8.76	1.57	8.09	1.25
	Sugar beets	19.17	4.11	17.85	4.11
	Tomatoes, F	27.86	6.48	27.44	6.32
	Tomatoes, P	30.20	7.37	29.55	7.12
	Wheat	5.58	1.04	5.45	0.97
5	Barley	6.50	1.55	6.32	1.45
	Beans	16.75	3.76	16.15	3.53
	Corn	11.15	3.50	10.72	3.28
	Gr. sorghum	9.30	3.42	9.03	3.31
	Rice	19.54	0.79	--	--
	Safflower	8.76	1.57	8.76	1.57
	Sugar beets	18.07	4.11	16.97	4.11
	Tomatoes, P	30.46	7.47	29.78	7.21
	Wheat	6.52	1.56	6.33	1.46
6	Barley	6.82	1.73	6.57	1.59
	Beans	15.82	3.41	15.33	3.23
	Corn	10.80	3.32	10.41	3.11
	Gr. sorghum	8.11	2.92	7.92	3.26

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Region	Cropping activity	Type I soil Total diesel	Type I soil Total gasoline	Type II soil Total diesel	Type II soil Total gasoline
		gallons per acre			
	Onions	33.20	11.18	32.94	11.06
	Potatoes	25.00	5.15	24.31	4.89
	Sugar beets	19.17	4.11	19.17	4.11
	Wheat	7.34	2.02	7.09	1.88
7	Barley	6.20	1.39	5.82	1.18
	Beans	17.98	4.22	17.36	3.99
	Broccoli	37.43	14.26	37.05	13.70
	Carrots	35.46	11.40	34.58	11.18
	Cauliflower	33.57	15.18	33.20	14.64
	Celery	37.87	17.99	37.12	16.89
	Corn	10.57	3.20	10.26	3.04
	Lettuce	24.89	11.59	24.30	10.94
	Onions	33.20	11.18	32.94	11.06
	Potatoes	25.00	5.15	24.31	12.28
	Sugar beets	19.17	4.11	17.85	4.11
	Tomatoes, F	27.73	6.42	27.34	6.28
	Tomatoes, P	30.46	7.48	29.78	7.21
8	Barley	6.20	1.39	6.07	1.31
	Beans	16.75	3.76	16.13	3.53
	Broccoli	36.09	12.30	35.89	12.02
	Cantaloupes	18.59	18.04	17.73	16.58
	Cauliflower	33.13	14.54	32.83	14.10
	Corn	10.57	3.20	10.25	3.03
	Cotton	21.30	5.38	21.10	5.09
	Gr. sorghum	8.57	3.12	8.38	3.03
	Onions	33.46	11.30	33.17	11.16
	Rice	20.00	0.84	--	--
	Safflower	8.76	1.57	8.76	1.57
	Sugar beets	18.51	4.11	17.32	4.11
	Tomatoes, F	25.78	5.67	25.57	5.60
	Tomatoes, P	30.46	7.47	29.78	7.21
	Wheat	6.34	1.46	6.08	1.32
9	Barley	6.20	1.39	5.82	1.17
	Beans	17.98	4.22	17.36	3.98
	Carrots	35.41	11.38	33.42	14.96
	Cauliflower	33.80	15.50	24.30	10.94
	Lettuce	24.89	11.59	33.21	11.19
	Onions	33.59	11.36	23.93	4.75
	Potatoes	24.57	4.99	17.50	4.11
	Sugar beets	18.73	4.11	29.78	7.22
	Tomatoes, F	25.46	6.70	27.99	6.52
	Tomatoes, P	30.46	7.47	5.71	1.11
	Wheat	5.83	1.18	34.53	11.17
10	Barley	6.57	1.58	6.32	1.45
	Beans	17.98	4.22	17.36	3.98
	Cantaloupes	17.81	16.91	17.49	15.61
	Corn	10.80	3.32	10.41	3.12
	Cotton	20.98	4.93	20.83	4.70
	Gr. sorghum	8.57	3.12	8.39	3.04

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Region	Cropping activity	Type I soil Total diesel	Type I soil Total gasoline	Type II soil Total diesel	Type II soil Total gasoline
		gallons per acre			
	Lettuce	24.89	11.59	24.30	10.95
	Onions	33.20	11.18	32.94	11.06
	Potatoes	23.50	4.59	22.98	4.40
	Rice	18.94	0.74	--	--
	Safflower	9.10	1.73	9.10	1.73
	Sugar beets	18.44	4.11	17.28	4.11
	Tomatoes, F	28.90	6.88	28.38	6.67
	Tomatoes, P	30.59	7.52	29.91	7.28
	Wheat	6.84	1.74	6.59	1.60
11	Barley	6.82	1.73	6.57	1.59
	Beans	19.82	4.90	19.21	4.67
	Cantaloupes	17.81	16.91	17.49	15.61
	Carrots	35.31	11.36	34.43	11.14
	Corn	10.77	3.30	10.41	3.12
	Cotton	21.30	5.38	21.10	5.10
	Gr. sorghum	8.57	3.12	8.39	3.04
	Lettuce	25.38	12.13	24.74	11.43
	Onions	33.07	11.12	32.82	11.01
	Potatoes	25.43	5.31	24.70	10.96
	Rice	18.49	0.70	--	--
	Safflower	9.30	1.82	9.32	1.82
	Sugar beets	17.63	4.11	16.62	4.11
	Tomatoes, F	27.34	6.28	26.98	6.14
	Tomatoes, P	30.20	7.37	29.55	7.12
	Wheat	6.84	1.74	6.59	1.60
12	Barley	6.20	1.39	5.82	1.17
	Beans	16.75	3.76	16.13	3.53
	Broccoli	36.09	12.30	35.89	12.02
	Cantaloupes	17.81	16.91	17.49	15.61
	Carrots	36.29	11.60	35.31	11.36
	Cauliflower	34.24	16.14	33.80	15.50
	Celery	37.22	17.04	36.52	16.01
	Lettuce	24.65	11.32	24.11	10.73
	Onions	33.20	11.18	32.94	11.06
	Sugar beets	19.39	4.11	18.03	4.11
	Tomatoes, F	29.68	7.17	28.54	6.74
	Tomatoes, P	29.42	7.07	28.85	6.85
13	Barley	6.20	1.39	5.82	1.17
	Beans	16.75	3.76	16.13	3.53
	Cantaloupes	17.81	16.91	17.49	15.61
	Cotton	21.98	4.93	20.83	4.70
	Onions	32.68	10.94	32.47	10.84
	Potatoes	22.85	4.35	22.38	4.17
	Safflower	8.76	1.57	8.76	1.57
	Sugar beets	19.17	4.11	17.85	4.11
	Tomatoes, F	26.30	5.88	26.04	5.78
	Tomatoes, P	30.72	7.57	30.02	7.30
	Wheat	5.96	1.25	5.83	1.18

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Region	Cropping activity	Type I soil		Type II soil	
		Total diesel	Total gasoline	Total diesel	Total gasoline
		gallons per acre			
14	Barley	7.45	2.08	7.19	1.93
	Beans	16.75	3.76	16.13	3.53
	Cantaloupes	17.21	14.48	16.97	13.50
	Carrots	32.86	10.76	32.22	10.60
	Cotton	21.57	5.77	21.33	5.44
	Gr. sorghum	8.57	3.12	8.39	3.04
	Lettuce	24.89	11.59	24.30	10.94
	Onions	32.58	10.90	32.38	10.80
	Sugar beets	18.73	4.11	17.50	4.11
	Tomatoes, F	26.40	5.92	26.14	5.82
	Tomatoes, P	30.72	7.57	30.02	7.30
	Wheat	7.47	2.09	7.22	1.95

APPENDIX B

YIELDS AND PRODUCTION COSTS, ACTUAL 1972 AND ESTIMATED 1977

Table B.1

1972 Regional Crop Yields, by Soil Type, with Associated Price-Forecasting Equation Quantity Units and Acres Per Unit

Region	Cropping activity	Yield/acre: Type I soil	Yield/acre: Type II soil	Price-forecasting equation quantity units	Acres per quantity unit: Type I soil	Acres per quantity unit: Type II soil
		tons		item	acres	
1	Beans	1.0	0.9	1,000 cwt	50.00	55.55
	Potatoes	14.0	12.6	1,000 cwt	3.60	3.96
	Tomatoes (fresh)	5.2	4.7	1,000 cwt	9.62	10.63
2	Barley	1.2	1.1	1,000 bu	20.00	21.81
	Corn	1.7	1.5	1,000 bu	16.50	18.66
	Wheat	1.2	1.1	1,000 bu	25.00	27.27
3	Barley	1.9	1.7	1,000 bu	12.63	14.11
	Beans	2.1	1.9	1,000 cwt	23.81	26.31
	Carrots	14.0	12.6	1,000 cwt	3.57	3.96
	Corn	3.5	3.0	1,000 bu	8.00	9.33
	Gr. sorghum	3.0	2.7	1,000 bu	9.33	10.37
	Lettuce	11.0	9.9	1,000 cwt	4.55	5.05
	Onions	18.0	16.2	1,000 cwt	2.77	3.08
	Potatoes	15.5	14.0	1,000 cwt	3.23	3.57
	Rice	--	2.7	1,000 cwt	--	18.52
	Safflower	1.6	1.6	1,000 tons	625.00	625.00
	Sugar beets	30.0	24.0	1,000 tons	30.33	41.66
	Tomatoes, F	21.0	18.9	1,000 cwt	2.38	2.64
	Tomatoes, P	25.0	22.5	Tons	0.04	0.04
	Wheat	2.5	2.3	1,000 bu	12.00	13.04
4	Barley	1.5	1.1	1,000 bu	16.00	21.81
	Broccoli	3.5	3.2	1,000 cwt	14.29	15.62
	Cauliflower	5.0	4.5	1,000 cwt	10.00	11.11
	Celery	23.0	20.1	1,000 cwt	2.17	2.48
	Lettuce	11.3	10.2	1,000 cwt	4.43	4.90
	Onions	19.5	17.6	1,000 cwt	2.56	2.84
	Safflower	1.0	0.5	1,000 tons	1000.00	2000.00
	Sugar beets	30.0	24.0	1,000 tons	33.33	41.66
	Tomatoes, F	16.0	14.4	1,000 cwt	3.12	3.47
	Tomatoes, P	25.0	22.5	Tons	0.04	0.04
	Wheat	1.0	0.9	1,000 bu	30.00	33.33
5	Barley	1.8	1.6	1,000 bu	13.71	15.00
	Beans	1.0	0.9	1,000 cwt	50.00	55.55
	Corn	3.8	3.2	1,000 bu	7.47	8.75
	Gr. sorghum	3.3	3.0	1,000 bu	8.48	9.33
	Rice	--	2.9	1,000 cwt	--	17.54
	Safflower	1.0	1.0	1,000 tons	1000.00	1000.00
	Sugar beets	25.0	20.0	1,000 tons	40.00	50.00
	Tomatoes, P	26.0	23.4	Tons	0.04	0.04
	Wheat	1.8	1.6	1,000 bu	17.14	18.75
6	Barley	2.0	1.8	1,000 bu	12.00	13.33
	Beans	0.9	0.8	1,000 cwt	58.82	64.93
	Corn	3.3	2.8	1,000 bu	8.48	10.00
	Gr. sorghum	2.0	1.8	1,000 bu	14.00	55.55
	Onions	20.0	18.0	1,000 cwt	2.50	2.77
	Potatoes	16.0	14.4	1,000 cwt	3.13	3.47
	Rice	2.9	--	1,000 cwt	17.54	--
	Sugar beets	30.0	24.0	1,000 tons	33.33	41.66
	Wheat	2.4	2.2	1,000 bu	12.50	13.63

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Region	Cropping activity	Yield/acre: Type I soil	Yield/acre: Type II soil	Price-forecasting equation quantity units	Acres per quantity unit: Type I soil	Acres per quantity unit: Type II soil
		tons		item	acres	
7	Barley	1.5	1.2	1,000 bu	16.00	20.00
	Beans	1.2	1.1	1,000 cwt	41.67	45.45
	Broccoli	3.9	3.5	1,000 cwt	12.82	14.28
	Carrots	18.3	16.5	1,000 cwt	2.73	3.03
	Cauliflower	5.1	4.6	1,000 cwt	9.80	10.86
	Celery	29.5	26.6	1,000 cwt	1.69	1.87
	Corn	3.0	2.6	1,000 bu	9.33	10.76
	Lettuce	12.0	10.8	1,000 cwt	4.17	4.62
	Onions	20.0	18.0	1,000 cwt	2.50	2.77
	Potatoes	16.0	14.4	1,000 cwt	3.13	3.47
	Sugar beets	30.0	24.0	1,000 tons	33.33	41.66
	Tomatoes, F	15.5	14.0	1,000 cwt	3.25	3.57
	Tomatoes, P	26.0	23.4	Tons	0.04	0.04
8	Barley	1.5	1.4	1,000 bu	16.00	17.14
	Beans	1.0	0.9	1,000 cwt	50.00	55.55
	Broccoli	2.5	2.3	1,000 cwt	20.00	21.73
	Cantaloupes	8.7	7.8	1,000 cwt	5.75	6.41
	Cauliflower	4.5	4.1	1,000 cwt	11.11	12.19
	Corn	3.0	2.6	1,000 bu	9.33	10.76
	Cotton	0.5	0.5	500,000 lbs	500.00	555.55
	Gr. sorghum	2.5	2.3	1,000 bu	11.20	12.17
	Onions	22.0	19.8	1,000 cwt	2.27	2.52
	Rice	--	2.7	1,000 cwt	--	18.52
	Safflower	1.0	1.0	1,000 tons	1000.00	1000.00
	Sugar beets	27.0	21.6	1,000 tons	37.04	46.29
	Tomatoes, F	8.0	7.2	1,000 cwt	6.25	6.94
	Tomatoes, P	26.0	23.4	Tons	0.04	0.04
	Wheat	1.6	1.4	1,000 bu	18.75	21.42
9	Barley	1.5	1.2	1,000 bu	16.00	20.00
	Beans	1.2	1.1	1,000 cwt	41.67	45.45
	Carrots	18.2	16.4	1,000 cwt	2.75	3.04
	Cauliflower	5.4	4.9	1,000 cwt	9.26	10.20
	Lettuce	12.0	10.8	1,000 cwt	4.17	4.62
	Onions	23.0	20.1	1,000 cwt	2.17	2.48
	Potatoes	15.0	13.5	1,000 cwt	3.33	3.70
	Sugar beets	28.0	22.4	1,000 tons	35.71	44.64
	Tomatoes, F	18.3	16.5	1,000 cwt	2.73	3.03
	Tomatoes, P	26.0	23.4	Tons	0.04	0.05
	Wheat	1.2	1.1	1,000 bu	25.00	27.27
10	Barley	1.8	1.6	1,000 bu	13.33	15.00
	Beans	1.2	1.1	1,000 cwt	41.67	45.45
	Cantaloupes	8.0	7.2	1,000 cwt	6.25	6.94
	Corn	3.3	2.8	1,000 bu	8.48	10.00
	Cotton	0.4	0.4	500,000 lbs	595.24	657.89
	Gr. sorghum	2.5	2.3	1,000 bu	11.20	12.17
	Lettuce	12.0	10.8	1,000 cwt	4.17	4.62
	Onions	20.0	18.0	1,000 cwt	2.50	2.77
	Potatoes	12.5	11.3	1,000 cwt	4.00	4.42
	Rice	--	2.7	1,000 cwt	--	18.52
	Safflower	1.3	1.3	1,000 tons	800.00	800.00
	Sugar beets	26.7	21.4	1,000 tons	37.45	46.72
	Tomatoes, F	20.0	18.0	1,000 cwt	2.50	2.77
	Tomatoes, P	26.5	23.9	Tons	0.04	0.04
	Wheat	2.0	1.8	1,000 bu	15.00	16.66

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Region	Cropping activity	Yield/acre: Type I soil	Yield/acre: Type II soil	Price-forecasting equation quantity units	Acres per quantity unit: Type I soil	Acres per quantity unit: Type II soil
		tons		item	acres	
11	Barley	2.0	1.8	1,000 bu	12.00	13.33
	Beans	1.5	1.4	1,000 cwt	33.33	35.71
	Cantaloupes	8.0	7.2	1,000 cwt	6.25	6.94
	Carrots	18.0	16.2	1,000 cwt	2.77	3.08
	Corn	3.3	2.8	1,000 bu	8.62	10.00
	Cotton	0.5	0.5	500,000 lbs	500.00	555.55
	Gr. sorghum	2.5	2.3	1,000 bu	11.20	12.17
	Lettuce	13.0	11.7	1,000 cwt	3.85	4.27
	Onions	19.0	17.1	1,000 cwt	2.63	2.92
	Potatoes	17.0	15.3	1,000 cwt	2.94	3.26
	Rice	--	2.5	1,000 cwt	--	20.00
	Safflower	1.4	1.4	1,000 tons	714.29	714.28
	Sugar beets	23.0	18.4	1,000 tons	43.48	54.34
	Tomatoes, F	14.0	12.6	1,000 cwt	3.57	3.96
	Tomatoes, P	25.0	22.5	Tons	0.04	0.04
	Wheat	2.0	1.8	1,000 bu	15.00	16.66
12	Barley	1.5	1.2	1,000 bu	16.00	20.00
	Beans	1.0	0.9	1,000 cwt	50.00	55.55
	Broccoli	2.5	2.3	1,000 cwt	20.00	21.73
	Cantaloupes	8.0	7.2	1,000 cwt	6.25	6.94
	Carrots	20.0	18.0	1,000 cwt	2.50	2.77
	Cauliflower	6.0	5.4	1,000 cwt	8.33	9.25
	Celery	27.0	24.3	1,000 cwt	1.85	2.05
	Lettuce	11.5	10.4	1,000 cwt	4.35	4.80
	Onions	20.0	18.0	1,000 cwt	2.50	2.77
	Sugar beets	31.0	24.8	1,000 tons	32.26	40.32
	Tomatoes, F	23.0	18.6	1,000 cwt	2.17	2.68
	Tomatoes, P	22.0	19.8	Tons	0.05	0.05
13	Barley	1.5	1.2	1,000 bu	16.00	20.00
	Beans	1.0	0.9	1,000 cwt	50.00	55.55
	Cantaloupes	8.0	7.2	1,000 cwt	6.25	6.94
	Cotton	0.4	0.4	500,000 lbs	595.24	657.89
	Onions	16.0	14.4	1,000 cwt	3.13	3.47
	Potatoes	11.0	9.9	1,000 cwt	4.55	5.05
	Safflower	1.0	1.0	1,000 tons	1000.00	1000.00
	Sugar beets	30.0	24.0	1,000 tons	33.33	41.66
	Tomatoes, F	10.0	9.0	1,000 cwt	5.00	5.55
	Tomatoes, P	27.0	24.3	Tons	0.04	0.04
	Wheat	1.3	1.2	1,000 bu	23.08	25.00
14	Barley	2.5	2.3	1,000 bu	9.60	10.43
	Beans	1.0	0.9	1,000 cwt	50.00	55.55
	Cantaloupes	6.5	5.9	1,000 cwt	7.69	8.47
	Carrots	13.0	11.7	1,000 cwt	3.85	4.27
	Cotton	0.6	0.5	500,000 lbs	438.60	490.19
	Gr. sorghum	2.5	2.3	1,000 bu	9.60	12.17
	Lettuce	12.0	10.8	1,000 cwt	4.17	4.62
	Onions	15.3	13.7	1,000 cwt	3.28	3.64
	Sugar beets	28.0	22.4	1,000 tons	35.71	44.64
	Tomatoes, F	10.4	9.4	1,000 cwt	4.81	5.31
	Tomatoes, P	27.0	24.3	Tons	0.04	0.04
	Wheat	2.5	2.3	1,000 bu	12.00	13.04

Table B. 2

Projected Increase in Per Acre Crop Yields
for 1976-77, From 1972 Levels

Crop	1962-72 Observed percentage increase in yield a/	1962-72 Annual percentage increase	Projected 1976-77 percentage increase in yield over 1972 levels
	percent	percent	percent
Barley	18	1.8	7.2
Beans	7	.7	2.8
Broccoli	3	.3	1.2
Cantaloupes	13	1.3	5.2
Carrots	11	1.1	4.4
Cauliflower	13	1.3	5.2
Celery	2	.2	.8
Corn	25	2.5	10.0
Cotton	16	1.6	6.4
Gr. sorghum	20	2.0	8.0
Lettuce	15	1.5	6.0
Onions	11	1.1	4.4
Potatoes	12	1.2	4.8
Rice	18	1.8	7.2
Safflower	34	3.4	13.60
Sugar beets	12	1.2	4.8
Tomatoes, fresh	18	1.8	7.2
Tomatoes, processed	30	3.0	12.0
Wheat	16	1.6	6.4

a/ Source: University of California Task Force General Report, A Hungry World: The Challenge to Agriculture, University of California Division of Agricultural Sciences, July, 1974.

Table B-3

1977 Crop Yields, by Soil Type, for 0, 20 and 40 Percent Reductions in Applied Nitrogen

Region	Cropping activity	1977 Yields with adequate nitrogen supplies		1977 Yields associated with a 20 percent reduction in applied nitrogen		1977 Yields associated with a 40 percent reduction in applied nitrogen	
		Type I soil	Type II soil	Type I soil	Type II soil	Type I soil	Type II soil
		tons					
1	Beans	1.03	0.93	0.9	0.8	0.8	0.6
	Potatoes	14.67	13.20	13.4	12.1	13.0	11.7
	Tomatoes, F	5.57	5.04	4.9	4.5	4.7	4.3
2	Barley	1.29	1.18	1.0	0.9	0.8	0.7
	Corn	1.87	1.65	1.6	1.4	1.4	1.2
	Wheat	1.28	1.17	1.1	1.0	1.0	0.9
3	Barley	2.04	1.82	1.6	1.4	1.3	1.2
	Beans	2.16	1.95	1.9	1.7	1.6	1.4
	Carrots	14.62	13.15	12.6	11.3	11.5	9.4
	Corn	3.85	3.30	3.4	2.9	2.9	2.5
	Gr. sorghum	3.24	2.92	2.7	2.4	2.4	2.2
	Lettuce	11.66	10.50	10.7	9.6	10.2	9.2
	Onions	18.79	16.91	17.5	15.7	16.7	15.1
	Potatoes	16.24	14.67	14.9	13.4	14.4	13.0
	Rice	--	3.22	--	2.7	--	2.0
	Safflower	1.82	1.82	1.4	1.4	1.2	1.2
	Sugar beets	31.44	25.15	29.1	23.3	27.9	22.3
	Tomatoes, F	22.51	20.26	20.0	18.0	19.1	17.2
	Tomatoes, P	28.00	25.20	24.0	21.6	23.0	20.7
	Wheat	2.66	2.45	2.2	2.0	2.0	1.9
4	Barley	1.61	1.18	1.2	0.9	0.8	0.7
	Broccoli	3.54	3.24	3.4	3.1	3.2	2.9
	Cauliflower	5.26	4.73	4.5	4.1	3.8	3.4
	Celery	23.20	20.26	22.3	19.5	21.6	18.9
	Lettuce	12.00	10.81	11.0	9.9	10.5	9.5
	Onions	20.36	18.37	18.5	17.1	18.1	16.4
	Safflower	1.14	0.57	0.9	0.5	0.8	0.4
	Sugar beets	31.44	25.15	29.1	23.3	27.9	22.3
	Tomatoes, F	17.15	15.45	15.2	13.5	14.6	12.8
	Tomatoes, P	28.00	25.20	24.0	20.3	23.0	16.9
	Wheat	1.06	0.96	0.9	0.8	0.8	0.7
5	Barley	1.93	1.72	1.5	1.4	1.2	1.1
	Beans	1.03	0.93	0.9	0.8	0.8	0.7
	Corn	4.18	3.52	3.6	3.1	3.1	2.7
	Gr. sorghum	3.56	3.24	3.0	2.7	2.6	2.4
	Rice	--	3.11	--	2.7	--	2.2
	Safflower	1.14	1.14	0.9	0.9	0.8	0.8
	Sugar beets	26.20	21.0	24.3	19.4	23.3	18.6
	Tomatoes, P	29.10	26.21	25.0	22.5	23.9	21.5
	Wheat	1.92	1.70	1.5	1.4	1.4	1.3
6	Barley	2.14	1.93	1.7	1.5	1.4	1.2
	Beans	0.93	0.82	0.8	0.7	0.6	0.6
	Corn	3.63	3.08	3.2	2.7	2.7	2.3
	Gr. sorghum	2.16	1.94	1.8	1.6	1.6	1.4
	Onions	20.88	18.79	19.4	17.5	18.6	16.7
	Potatoes	16.77	15.09	15.4	13.8	14.9	13.4
	Sugar beets	31.44	25.15	29.1	23.3	27.9	22.3
	Wheat	2.55	2.34	2.1	1.9	1.9	1.8
7	Barley	1.61	1.29	1.1	1.0	0.9	0.8
	Beans	1.23	1.13	1.1	1.0	0.9	0.8
	Broccoli	3.95	3.54	3.7	3.4	3.5	3.2
	Carrots	19.11	17.23	16.4	14.9	13.7	12.4
	Cauliflower	5.34	4.84	4.6	4.1	3.8	3.4
	Celery	29.74	26.81	28.6	25.8	27.7	25.0
	Corn	3.30	2.86	2.9	2.5	2.5	2.2

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(Continued)

Region	Cropping activity	1977 Yield with adequate nitrogen supplies		1977 Yields associated with a 20 percent reduction in applied nitrogen		1977 Yields associated with a 40 percent reduction in applied nitrogen	
		Type I soil	Tape II soil	Type I soil	Type II soil	Type I soil	Type II soil
		tons					
	Lettuce	12.72	11.45	11.6	10.5	11.2	10.0
	Onions	20.88	18.79	18.6	16.7	18.0	16 0
	Potatoes	16.77	15.09	15.4	13.8	14.9	13.4
	Sugar beets	31.44	25.15	29.1	21.6	27.9	18.0
	Tomatoes F	16.60	15.00	14.7	13.3	14.1	12.7
	Tomatoes P	29.10	26.20	25.0	22.5	23.9	21.5
8	Barley	1.61	1.50	1.3	1.2	1.0	1.0
	Beans	1.03	0.93	0.9	0.8	0.8	0.7
	Broccoli	2.53	2.33	2.4	2.2	2.3	2.1
	Cantaloupes	9.15	8.21	8.5	7.6	8.3	7.4
	Cauliflower	4.73	4.31	4.1	3.3	3.4	2.6
	Corn	3.30	2.86	2.9	2.5	2.5	2.2
	Cotton	.53	.53	0.5	0.4	0.4	0.3
	Gr. sorghum	2.70	2.48	2.3	2.1	2.0	1.8
	Onions	22.97	20.67	21.3	19.2	20.5	18.4
	Rice	--	2.89	--	2.7	--	2.3
	Safflower	1.14	1.14	0.9	0.9	0.8	0.8
	Sugar beets	28.30	22.64	26.2	21.0	25.1	20.1
	Tomatoes F	8.60	7.72	7.6	6.8	7.3	6.6
	Tomatoes P	29.12	26.21	25.0	22.2	23.9	21.3
	Wheat	1.70	1.50	1.4	1.2	1.3	1.1
9	Barley	1.61	1.29	1.1	1.0	0.9	0.8
	Beans	1.23	1.13	1.1	1.0	0.9	0.8
	Carrots	19.00	17.12	16.4	14.7	13.7	12.3
	Cauliflower	5.68	5.15	4.9	4.5	4.1	3.7
	Lettuce	12.72	11.45	11.6	10.5	11.2	10.0
	Onions	24.00	20.98	22.3	19.5	21.4	18.7
	Potatoes	15.72	14.15	14.4	12.2	14.0	12.6
	Sugar beets	29.34	23.50	27.2	21.7	26.0	20.8
	Tomatoes F	19.60	17.70	17.4	15.7	16.7	15.0
	Tomatoes P	29.10	26.20	25.0	22.5	23.9	21.5
	Wheat	1.28	1.17	1.1	1.0	1.0	0.9
10	Barley	1.93	1.72	1.2	1.4	1.2	1.1
	Beans	1.23	1.13	1.1	1.0	0.9	0.8
	Cantaloupes	8.42	7.57	7.6	7.1	7.0	6.8
	Corn	3.63	3.08	2.7	2.7	2.7	2.3
	Cotton	0.43	0.43	0.4	0.4	0.3	0.3
	Gr. sorghum	2.70	2.48	2.1	2.0	2.0	1.8
	Lettuce	12.72	11.45	11.2	10.5	11.0	10.0
	Onions	20.88	18.79	18.6	17.5	16.6	13.5
	Potatoes	13.10	11.84	11.6	10.8	10.6	9.5
	Rice	--	2.89	--	2.0	--	2.0
	Safflower	1.48	1.48	1.1	1.1	0.9	0.8
	Sugar beets	28.00	22.43	24.8	20.8	22.8	19.9
	Tomatoes F	21.40	19.30	18.2	17.1	18.0	16.4
	Tomatoes P	29.70	26.80	24.4	22.9	23.4	22.0
	Wheat	2.13	1.92	1.6	1.6	1.6	1.5
11	Barley	2.14	1.93	1.7	1.5	1.4	1.2
	Beans	1.54	1.44	1.4	1.3	1.1	1.1
	Cantaloupes	8.42	7.57	7.8	7.1	7.8	6.8
	Carrots	18.79	16.91	16.2	14.6	14.5	12.2
	Corn	3.63	3.08	3.1	2.7	3.1	2.3
	Cotton	0.53	0.53	0.5	0.4	0.4	0.3
	Gr. sorghum	2.70	2.48	2.3	2.1	2.2	1.8
	Lettuce	13.78	12.40	12.6	11.3	12.0	10.9
	Onions	19.84	17.85	18.4	16.6	18.0	15.9
	Potatoes	17.82	16.03	16.3	14.7	15.3	14.2
	Rice	--	2.68	--	2.2	--	2.0
	Safflower	1.59	1.59	1.3	1.3	1.1	1.0
	Sugar beets	24.10	19.28	22.3	17.8	21.3	17.1
	Tomatoes F	15.00	13.50	13.3	12.0	12.3	11.5
	Tomatoes P	28.00	25.20	24.0	21.6	23.0	20.7
	Wheat	2.13	1.92	1.8	1.6	1.8	1.5

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Region	Cropping activity	1977 Yield with adequate nitrogen supplies		1977 Yields associated with a 20 percent reduction in applied nitrogen		1977 Yields associated with a 40 percent reduction in applied nitrogen	
		Type I soil	Type II soil	Type I soil	Type II soil	Type I soil	Type II soil
		tons					
12	Barley	1.61	1.29	1.1	1.0	0.9	0.8
	Beans	1.03	0.93	0.9	0.8	0.8	0.7
	Broccoli	2.53	2.33	2.4	2.2	2.3	2.1
	Cantaloupes	8.42	7.57	7.8	7.1	7.6	6.8
	Carrots	20.88	18.79	18.0	16.2	16.0	13.7
	Cauliflower	6.31	5.68	5.4	4.9	4.5	3.8
	Celery	28.16	26.14	26.2	23.6	25.4	22.8
	Lettuce	12.19	11.00	11.2	10.1	10.7	9.7
	Onions	20.88	18.79	19.4	17.5	18.6	16.7
	Sugar beets	32.50	26.00	30.1	24.1	28.8	23.1
	Tomatoes F	24.66	19.94	21.9	17.7	20.9	16.9
	Tomatoes P	24.60	22.20	21.1	19.0	20.2	18.2
13	Barley	1.61	1.29	1.1	1.0	0.9	0.8
	Beans	1.03	0.93	0.9	0.8	0.8	0.7
	Cantaloupes	8.42	7.57	7.8	7.1	7.6	6.8
	Cotton	0.43	0.43	0.4	0.3	0.3	0.3
	Onions	17.6	15.9	15.5	14.0	14.9	13.4
	Potatoes	11.53	10.38	10.6	9.5	10.2	9.2
	Safflower	1.14	1.14	0.9	0.9	0.8	0.8
	Sugar beets	31.44	25.15	29.1	23.3	27.9	22.3
	Tomatoes F	10.72	9.65	9.5	8.6	9.1	8.2
	Tomatoes P	30.00	27.22	25.9	23.3	24.8	22.4
	Wheat	1.38	1.28	1.1	1.1	1.1	1.0
14	Barley	2.68	2.47	2.1	2.0	1.7	1.6
	Beans	1.03	0.93	0.9	0.8	0.8	0.7
	Cantaloupes	6.84	6.21	6.4	5.6	6.2	5.6
	Carrots	13.57	12.22	11.7	10.6	9.8	8.8
	Cotton	0.64	0.53	0.5	0.5	0.4	0.4
	Gr. sorghum	2.70	2.48	2.3	2.1	1.9	1.7
	Lettuce	12.72	11.45	11.6	10.0	11.2	10.0
	Onions	15.97	14.30	14.8	12.7	14.2	12.7
	Sugar beets	29.34	23.50	27.2	20.9	26.0	20.9
	Tomatoes F	11.15	10.08	9.9	8.6	9.5	8.6
	Tomatoes P	30.00	27.20	25.9	22.4	24.8	22.4
	Wheat	2.66	2.45	2.2	1.9	2.0	1.9

Table B.4

1972 Regional Variable Production Costs (Excluding Land and Management), by Soil Type

Region	Cropping activity	Variable production costs per acre: Total variable costs, type I soil	Total variable costs, type II soil
		dollars per acre	
1	Beans	144.30	138.80
	Potatoes	462.7	440.20
	Tomatoes, F	991.90	921.90
2	Barley	28.36	28.19
	Corn	90.29	88.91
	Potatoes	462.7	440.20
	Wheat	28.36	28.19
3	Barley	29.56	29.22
	Beans	171.5	161.70
	Carrots	806.30	750.5
	Corn	73.50	71.45
	Gr. sorghum	57.57	56.22
	Lettuce	988.26	922.60
	Onions	1130.54	1036.00
	Potatoes	781.10	748.50
	Rice	--	122.20
	Safflower	50.71	50.71
	Sugar beets	217.54	198.80
	Tomatoes, P	433.73	413.60
	Tomatoes, F	3214.00	2919.00
	Wheat	30.87	30.55
4	Barley	28.36	28.19
	Broccoli	560.40	537.90
	Cauliflower	924.90	865.90
	Celery	1932.00	1772.00
	Lettuce	983.14	916.50
	Onions	811.10	759.80
	Safflower	45.02	40.28
	Sugar beets	282.50	265.80
	Tomatoes, P	614.20	579.90
	Tomatoes, F	2511.00	2287.00
	Wheat	28.02	27.85
5	Barley	29.29	29.04
	Beans	142.91	138.79
	Corn	104.39	100.60
	Gr. sorghum	83.37	82.79
	Rice	123.87	114.59
	Safflower	42.31	42.21
	Sugar beets	211.72	198.59
	Tomatoes, P	392.96	372.15
	Wheat	31.43	30.30

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(Continued.)

Region	Cropping activity	Variable production costs per acre: Total variable costs, type I soil	Total variable costs, type II soil
		dollars per acre	
6	Barley	48.65	47.51
	Beans	97.30	92.98
	Corn	95.24	91.41
	Gr. sorghum	50.96	49.27
	Onions	427.77	416.51
	Potatoes	462.76	440.24
	Sugar beets	224.80	206.60
	Wheat	45.89	44.20
7	Barley	39.66	39.49
	Beans	187.71	182.09
	Broccoli	590.41	560.40
	Carrots	975.90	906.70
	Cauliflower	939.61	877.71
	Celery	2291.09	2131.00
	Corn	92.95	89.86
	Lettuce	1024.45	884.79
	Onions	824.58	770.64
	Potatoes	788.28	757.21
	Sugar beets	284.59	265.76
	Tomatoes, P	682.65	592.23
	Tomatoes, F	2441.00	2230,00
8	Barley	47.80	47.02
	Beans	190.60	185.60
	Broccoli	485.40	470.40
	Cantaloupes	338.30	318.50
	Cauliflower	865.90	818.80
	Corn	91.02	89.86
	Cotton	233.65	233.64
	Gr. sorghum	76.68	73.45
	Onions	878.50	819.20
	Rice	--	126.30
	Safflower	63.38	63.38
	Sugar beets	217.98	199.34
	Tomatoes, P	428.45	406.95
	Tomatoes, F	1387.66	1275.28
	Wheat	59.38	57.98
9	Barley	28.53	28.36
	Beans	191.14	185.65
	Carrots	902.08	846.22
	Cauliflower	972.00	913.10
	Lettuce	1095.98	884.79
	Onions	713.08	647.12
	Potatoes	770.00	737.70
	Sugar beets	263.25	247.42
	Tomatoes, P	523.95	460.32
	Tomatoes, F	2834.00	2582.00
	Wheat	28.68	28.51

(Table continued on next page.)

(Continued.)

Region	Cropping activity	Variable production costs per acre: Total variable costs, type I soil	Total variable costs, type II soil
		dollars per acre	
10	Barley	51.02	49.24
	Beans	136.43	131.15
	Cantaloupes	322.89	305.29
	Corn	108.44	103.99
	Cotton	215.09	207.57
	Gr. sorghum	80.02	78.75
	Lettuce	1119.96	969.95
	Onions	606.70	570.50
	Potatoes	620.75	588.14
	Rice	--	120.60
	Safflower	65.84	65.83
	Sugar beets	196.82	181.63
	Tomatoes, F	5783.64	4598.22
	Tomatoes, P	548.54	518.36
	Wheat	62.18	60.78
11	Barley	53.38	51.94
	Beans	127.62	121.15
	Cantaloupes	330.31	304.68
	Carrots	965.90	894.10
	Corn	106.13	102.45
	Cotton	251.46	240.39
	Gr. sorghum	80.41	78.99
	Lettuce	1130.52	1026.44
	Onions	576.50	542.20
	Potatoes	996.88	913.05
	Rice	--	118.20
	Safflower	76.38	76.38
	Sugar beets	215.53	203.39
	Tomatoes, F	3923.00	3686.00
	Tomatoes, P	543.47	519.53
	Wheat	54.75	53.42
12	Barley	28.52	28.36
	Beans	190.60	185.60
	Broccoli	485.40	470.40
	Carrots	1046.00	965.90
	Cauliflower	1043.00	972.00
	Celery	2153.00	2004.00
	Lettuce	924.50	862.10
	Onions	606.70	570.50
	Sugar beets	270.70	253.90
	Tomatoes, P	446.80	425.60
	Tomatoes, F	3495.00	2877.00

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(Continued.)

Region	Cropping activity	Variable production costs per acre: Total variable costs, type I soil	Total variable costs, type II soil
		dollars per acre	
13	Barley	28.52	28.36
	Beans	190.60	185.60
	Cotton	185.00	176.60
	Onions	522.30	493.40
	Potatoes	580.00	550.10
	Safflower	63.38	63.38
	Sugar beets	284.60	265.80
	Tomatoes, P	555.80	523.20
	Tomatoes, F	1669.00	1528.00
	Wheat	28.53	28.36
14	Barley	84.60	83.28
	Cantaloupes	679.16	639.72
	Carrots	1289.04	1087.63
	Cotton	261.31	257.08
	Gr. sorghum	84.09	82.77
	Lettuce	773.88	742.48
	Onions	1048.24	972.78
	Sugar beets	305.30	291.23
	Tomatoes, F	2034.94	1877.42
	Wheat	84.60	83.28

Table B.5

1977 Variable Per Acre Production Costs for Low and High Energy Cost Assumptions, by Soil Type

Region	Cropping activity	Low energy costs		High energy costs	
		Type I soil total cost	Type II soil total cost	Type I soil total cost	Type II soil total cost
		dollars per acre			
1	Beans	216.45	208.20	245.31	235.96
	Potatoes	694.00	660.30	786.60	748.34
	Tomatoes, fresh	1487.85	1382.85	1686.23	2350.85
2	Barley	42.54	42.29	48.21	47.92
	Corn	135.44	133.37	153.49	151.15
	Wheat	42.54	42.29	48.21	47.92
3	Barley	44.34	43.83	53.20	52.60
	Beans	257.24	226.36	284.67	268.41
	Carrots	1290.45	1125.75	1370.71	1275.85
	Corn	110.24	105.96	121.99	118.61
	Gr. sorghum	86.36	82.32	95.57	93.33
	Lettuce	1482.39	1285.35	1640.51	1531.47
	Onions	1695.81	1424.81	1876.70	1719.26
	Potatoes	1171.50	1122.75	1327.87	1272.45
	Rice	--	183.30	--	207.75
	Safflower	76.06	71.51	84.18	84.16
	Sugar beets	326.31	299.96	361.12	329.94
	Tomatoes, F	4821.00	4378.50	5463.80	4962.30
	Tomatoes, P	650.60	585.78	719.99	686.58
	Wheat	46.31	45.11	51.24	50.71
4	Barley	42.54	42.29	48.21	47.92
	Broccoli	840.60	806.85	952.68	914.43
	Cauliflower	1387.35	1298.85	1572.33	1472.03
	Celery	2898.00	2658.00	3284.40	3012.40
	Lettuce	1474.71	1271.00	1632.01	1521.46
	Onions	1216.65	1139.70	1378.87	1291.66
	Safflower	67.53	60.42	76.53	76.53
	Sugar beets	423.75	398.70	480.25	451.86
	Tomatoes, F	3766.50	3430.50	4268.70	3887.90
	Tomatoes, P	921.30	869.85	1044.15	985.83
	Wheat	42.03	41.77	47.63	47.35
5	Barley	43.94	43.05	48.62	48.21
	Beans	214.36	198.33	237.23	230.39
	Corn	156.58	148.84	173.29	167.00
	Gr. sorghum	125.06	122.79	138.39	137.43
	Rice	185.81	171.89	205.62	190.22
	Safflower	63.46	60.38	70.23	70.07
	Sugar beets	317.58	299.19	351.46	329.66
	Tomatoes, P	589.44	528.51	652.31	617.77
	Wheat	43.95	43.05	48.64	52.17
6	Barley	72.98	69.57	80.76	78.87
	Beans	145.95	132.18	161.52	154.35
	Corn	142.86	137.12	161.90	155.40
	Gr. sorghum	74.87	70.62	84.59	81.79
	Onions	641.66	607.88	710.10	691.41
	Potatoes	694.12	634.82	768.18	730.80
	Sugar beets	337.20	309.90	382.16	351.20
	Wheat	68.84	62.78	76.18	73.37

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(Continued.)

Region	Cropping activity	Low energy costs		High energy costs	
		Type I soil total cost	Type II soil total cost	Type I soil total cost	Type II soil total cost
		dollars per acre			
7	Barley	42.80	42.54	48.50	48.21
	Beans	281.56	259.31	311.60	302.27
	Broccoli	885.62	797.86	980.08	930.28
	Carrots	1463.85	1245.39	1619.99	1504.08
	Cauliflower	1409.42	1228.17	1559.75	1457.00
	Celery	3436.64	2948.37	3803.21	3537.61
	Corn	139.43	134.79	158.02	152.76
	Lettuce	1536.68	1310.85	1700.59	1468.75
	Onions	1236.87	1075.05	1368.80	1279.26
	Potatoes	1182.42	1079.13	1308.54	1256.97
	Sugar beets	426.88	401.14	472.42	441.16
	Tomatoes, F	3661.50	3345.00	4149.70	3791.00
	Tomatoes, P	1023.98	900.68	1133.20	983.10
8	Barley	71.70	68.21	79.35	78.05
	Beans	285.90	278.40	324.00	315.50
	Broccoli	728.10	705.60	825.20	799.70
	Cantaloupes	507.45	477.75	575.10	541.45
	Cauliflower	1298.85	1228.20	1472.00	1391.96
	Corn	136.53	130.17	151.09	149.17
	Cotton	350.62	324.64	387.86	387.84
	Gr. sorghum	115.02	110.18	127.29	121.93
	Onions	1317.75	1228.80	1493.45	1392.64
	Rice	--	189.45	--	214.71
	Safflower	95.07	95.07	107.75	107.75
	Sugar beets	326.97	301.76	361.85	330.90
	Tomatoes, F	2081.49	1744.36	2303.52	2116.96
	Tomatoes, P	642.68	579.28	711.23	675.54
	Wheat	89.07	86.84	100.95	98.57
9	Barley	42.80	42.54	48.50	48.21
	Beans	286.71	267.39	317.29	308.18
	Carrots	1269.33	1089.78	1497.45	1404.73
	Cauliflower	1458.00	1369.65	1652.40	1552.27
	Lettuce	1643.97	1396.68	1819.33	1468.75
	Onions	1069.62	940.88	1183.71	1074.22
	Potatoes	1155.00	1106.55	1309.00	1254.10
	Sugar beets	394.88	371.91	437.00	410.72
	Tomatoes, F	4251.00	3873.00	4817.80	4389.40
	Tomatoes, P	785.93	699.48	869.76	764.13
	Wheat	43.02	42.77	48.76	48.47
10	Barley	76.52	72.45	84.69	81.74
	Beans	204.64	185.55	226.47	217.71
	Cantaloupes	484.34	430.34	536.00	506.78
	Corn	162.66	154.28	180.01	172.62
	Cotton	322.64	296.59	357.05	344.57
	Gr. sorghum	120.03	115.27	132.83	130.73
	Lettuce	1679.94	1454.92	1859.13	1610.12
	Onions	910.05	855.75	1031.40	969.85
	Potatoes	931.12	829.23	1030.45	976.13
	Rice	--	180.90	--	205.00
	Safflower	98.76	95.07	109.29	109.28
	Sugar beets	295.23	272.25	326.72	301.51
	Tomatoes, F	8675.46	7405.86	9600.84	7634.21
	Tomatoes, P	822.81	727.21	970.34	860.48
	Wheat	93.27	89.07	103.22	100.89

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(Continued.)

Region	Cropping activity	Low energy costs		High energy costs	
		Type I soil total cost	Type II soil total cost	Type I soil total cost	Type II soil total cost
		dollars per acre			
11	Barley	80.07	75.76	88.61	86.22
	Beans	191.43	170.08	211.85	201.11
	Cantaloupes	495.46	438.36	548.31	505.77
	Carrots	1448.85	1341.15	1642.00	1519.95
	Corn	159.19	151.24	176.18	170.07
	Cotton	377.19	345.28	417.42	399.05
	Gr. sorghum	120.61	115.32	133.48	131.12
	Lettuce	1695.78	1461.61	1876.66	1703.89
	Onions	864.75	813.30	980.00	921.75
	Potatoes	1450.32	1324.44	1654.82	1515.66
	Rice	--	177.30	--	200.95
	Safflower	114.19	110.91	126.38	120.79
	Sugar beets	323.29	345.76	357.78	337.63
	Tomatoes, F	5884.50	5529.00	6669.00	6266.00
	Tomatoes, P	815.20	718.24	902.16	862.42
	Wheat	82.12	78.15	90.89	88.68
12	Barley	42.78	42.54	48.48	48.21
	Beans	285.90	278.40	324.00	315.50
	Broccoli	728.10	705.60	825.20	799.34
	Carrots	1569.00	1448.85	1778.20	1642.00
	Cauliflower	1564.50	1458.00	1773.10	1652.40
	Celery	3229.50	3006.00	3660.10	3406.80
	Lettuce	1386.75	1293.10	1571.65	1465.60
	Onions	910.05	855.75	1031.40	969.85
	Sugar beets	406.05	380.85	460.20	431.60
	Tomatoes, F	5242.50	4315.50	5941.50	4890.90
	Tomatoes, P	670.20	638.40	759.56	723.50
13	Barley	42.78	42.54	48.48	48.21
	Beans	285.90	278.40	324.00	315.50
	Cotton	367.50	354.90	416.50	402.20
	Onions	783.45	740.10	887.90	838.80
	Potatoes	870.00	825.10	986.00	935.10
	Safflower	95.07	95.07	107.75	107.75
	Sugar beets	426.90	398.70	483.80	451.86
	Tomatoes, F	2503.50	2292.00	2837.30	2597.60
	Tomatoes, P	833.70	784.95	944.90	889.40
	Wheat	42.80	42.54	48.50	48.20
14	Barley	126.90	121.98	140.44	138.24
	Cantaloupes	1018.74	867.30	1127.41	1061.94
	Carrots	1631.44	1378.80	2139.81	1805.47
	Cotton	391.96	378.91	433.77	426.75
	Gr. sorghum	126.13	121.21	139.59	137.40
	Lettuce	1160.82	548.50	1284.64	1232.52
	Onions	1572.36	1048.18	1740.08	1614.81
	Sugar beets	457.95	436.05	506.80	483.44
	Tomatoes, F	3052.41	2561.01	3378.00	3116.52
	Wheat	126.90	121.98	140.44	138.24